POST HARVEST TECHNOLOGY, COLD CHAIN MANAGEMENT & FOOD SAFETY ISSUES

A HANDBOOK 2008

INDO-US BILATERAL WORKSHOP-CUM-TRAINING ON "POST HARVEST TECHNOLOGY, COLD CHAIN MANAGEMENT & FOOD SAFETY ISSUE

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FOREWORD

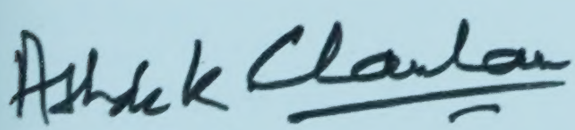
Lured by agri-production statistics which appear very attractive in print, we proudly proclaim that India is the second highest fruit and vegetable producer in the world, the highest producer of milk, fifth largest producer of eggs, sixth largest producer of fish, but when we look at the percentage of appalling wastage in the agricultural commodities, our spirits are instantly dampened. A considerable amount of the valuable produce is lost due to improper post harvest management and inadequate processing facility leading to instability in the prices, losses to farmers as well as the processors. Thus, impoverished India loses, 25-40% of the produce, a loss estimated at Rs. 80,000/- crores per year. The question is, how we can mitigate the staggering losses. India, the "Land of Agriculture" with all of its cultivable land, all the seasons for production of all the varieties of fruits and vegetables, a well-set agribusiness system that works, must gear up to tackle the challenges posed by post harvest losses which severely impact the small and marginal farmers. The imperative step that needs to be pursued vigorously involves building of sustainable supply chains, which assist the growers in accessing the marketing and processing centres. Minimizing wastage would necessarily maximize profitable return which requires a stable integrated system encompassing post-harvest technology and cold chain management. Food safety and quality have not received the importance they deserve especially for domestic consumption. It is heartening to note that Government of India has declared the year 2008-09 as the Food Safety and Quality year. But we need urgently to generate awareness regarding the global safety management systems and adherence to safety standards has to be closely monitored.

There is invariably a wide gap between the requirements and availability of training programmes addressing such needs for the industry and other stakeholders. This requires inter-disciplinary and multi-dimensional approach, which must include scientific creativity, technological innovations, commercial entrepreneurship and institutions capable of inter-disciplinary research and development in an integrated manner so as to meet the developmental needs of the country.

Amity is currently a leading education provider in India, offering industry oriented professional courses with focus on cutting edge research and innovation. Amity University is deeply committed to nation building through quality teaching and research and is running several programmes of immense importance. The week-long Indo-US Bilateral workshop-cum-training being organised by Amity Science, Technology & Innovation Foundation under Amity University is a major step in this direction. The event supported by Indo-US Science, Technology Forum is a unique programme, first of its kind in the country, in which five experts of international repute will deliver lectures, interact with participants and facilitate forging of collaborative research in the thrust areas of post-harvest technology, cold/cool chain management and food safety. The U.S. experts and their counterparts from India would interact on the current status of Indian agribusiness and would effectively sensitize the stakeholders in respect of the global standards that can be achieved by India. Long term benefits of a workshop-cum-training programme targeted to the industry, government and academia.

We at Amity genuinely take pride in welcoming **Dr. Abdul A Kader** a world-renowned post harvest technologist and his team of experts.

I wish this historic event all success.



Ashok K Chauhan
Founder President, Ritnand Balved Education Foundation (RBEF) &
Chairman, Amity Science, Technology & Innovation Foundation (ASTIF)

PREFACE

India in the new millennium has created a significant position for itself in the production of agriculture crops. Its transition from self sustenance to surplus production is remarkable. The country has emerged as the second largest producer of fruits and vegetables and the contribution of the agriculture sector to the country's Gross Domestic Product has been recorded at 18 per cent.

However, it is worth noting that this food basket has recorded a post harvest loss that is equivalent to United Kingdom's annual consumption. This has not only led to a lot of wastages but also discouraged international trade. Today India' share in world trade of fruits and vegetables is about 1% which is very low as compared to its production level and potential.

There is no authentic study of how much perishable agricultural commodities actually gets wasted in India due to lack of appropriate post harvest management, absence of cold chain infrastructure and other storage facilities. However, scholars have estimated these losses vary from 8 percent to 40 percent. Whatever be the actual percentage of wastage, it has to be admitted that it is still too large and totally unaffordable for a country like India, where 22 percent of citizens live below the poverty line.

The post harvest losses can be reduced by transporting the freshly harvested fruits and vegetables in refrigerated containers thus closing this gap in the cold chain. Not only better post harvest practices are required but, food safety norms should also be emphasized upon for a holistic approach to the concept of post harvest management.

Efficient management during the post harvest period, as well as upgradation of technology is the key to reaching the desired objective. Research activities in post harvest technology are being undertaken all over the country and world.

Global AgriSystem Pvt. Ltd. is an organization dedicated exclusively to the agriculture and food sector in India for the last ten years we have been working relentlessly to revitalize the Indian agribusiness sector. We recognize that there is an urgent need to compile the research work being carried out which will serve as a ready reference for growers, entrepreneurs, exporters, agriculture institutions, students. This book contains valuable contributions from well known experts for their contributions in post harvest technology, cold chain management and food safety issues. It is also intended for use as a reference source by government departments and policy makers with an interest in development of the perishable agriculture. It is hoped that the information presented in this book is helpful in improving post harvest practices in developing and developed countries, thereby leading to improvement in quality and safety of fruits and vegetables.

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We express our gratitude and sincere thanks to World Food Logistics Organization (WFLO) for granting permission to reproduce some parts of their book *Successful Refrigerated Warehousing.*

Publications of Dr. Adel A. Kader, Professor Emeritus of Post harvest Physiology, University of California, Davis, Dr. Lisa Kitinoja, Senior Technical Advisor, Fruits and Vegetables, World Food Logistics Organization (WFLO), USA and Dr. Susanta K. Roy, Prof. Emeritus, Amity Science, Technology and Innovation Foundation have greatly enhanced the value of the book which is gratefully acknowledged.

Sunil Saran
Vice Chairman
Amity Science, Technology & Foundation
& Workshop Convener

TABLE OF CONTENTS

LIST OF FIGURES:

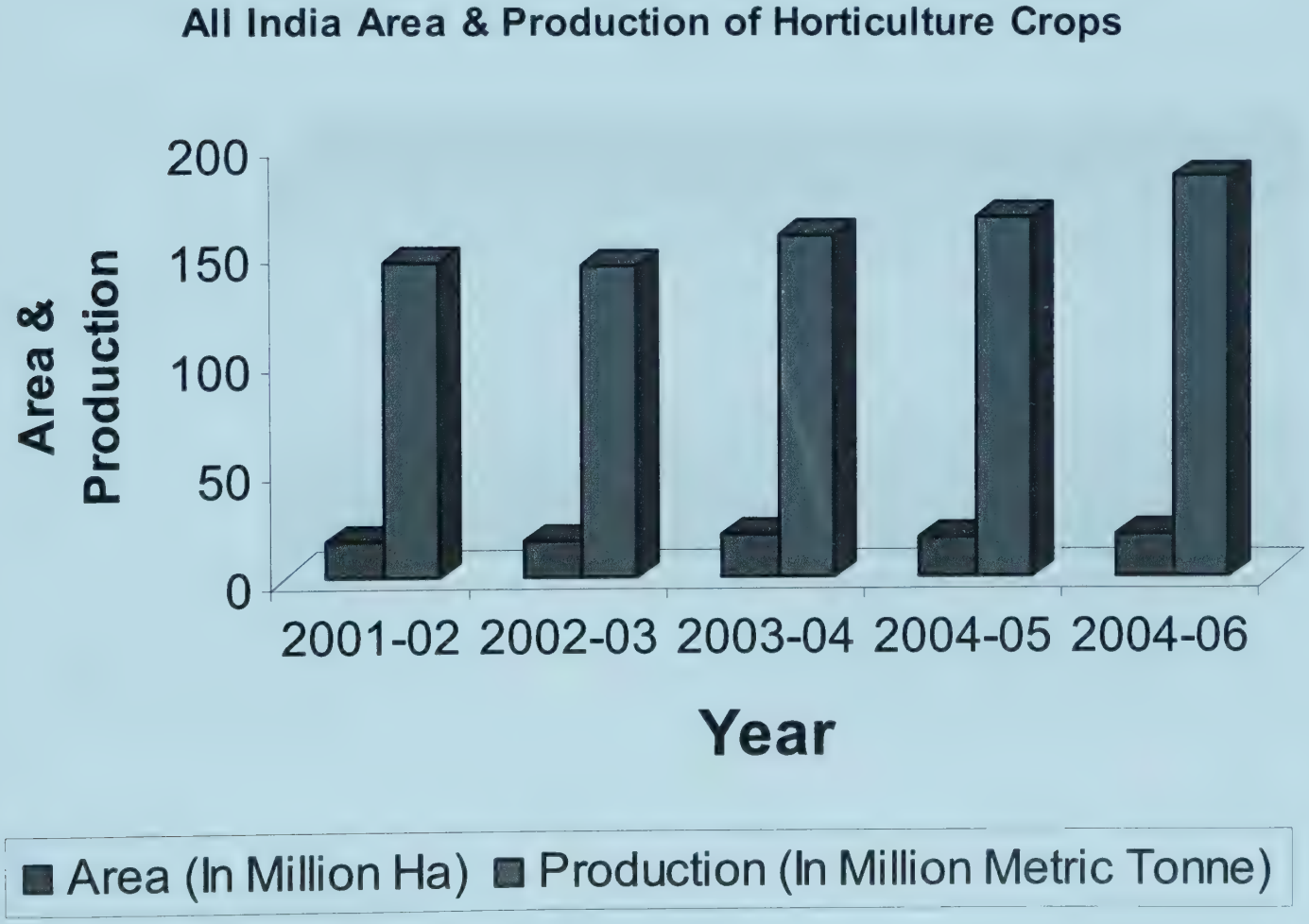
INTRODUCTION

Over the years India has achieved a significant position as one of the fastest growing economy in the world. In a robust demonstration of its nascent strength India has emerged as one of the stars of global economics in recent years, growing at 9.6 per cent in 2006-07 and 9 per cent in 2007-08, emerging as the second fastest growing economy in the world, thus breaking all previous barriers and surging ahead in the new millennium.

However, agriculture growth rate has not been significant, but it remains an important contributing factor in Indian Gross Domestic Product (GDP). This is due to the fact that the country is mainly based on the agriculture sector and employs around 60% of the total workforce in India. The agricultural sector contributed around 18% to India GDP in 2007. Within the agriculture sector horticulture plays a very important role.

Bestowed with varied agro-climatic conditions, India is favorable for growing a large number of horticultural crops such as fruits, vegetables, root tuber, aromatic and medicinal plants and spices and plantation crops like coconut, arecanut, cashew and cocoa. Presently, horticultural crops occupy around 13 per cent of India's gross cropped area, producing 177.41 million metric tones during 2005-06.

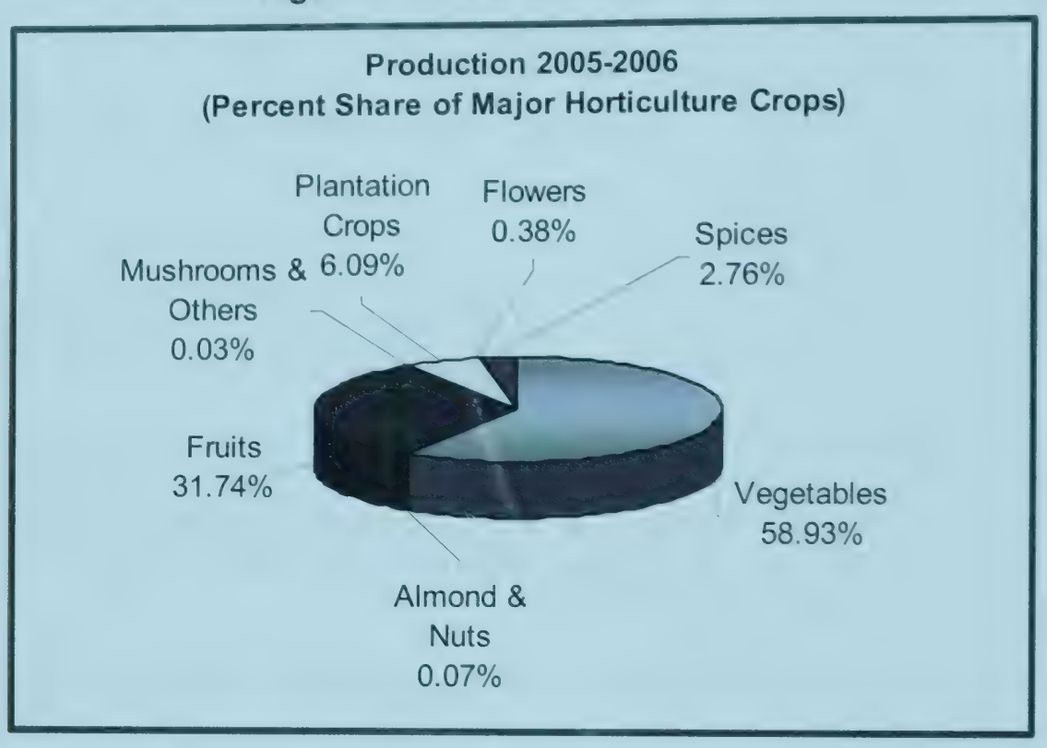
Figure 1 Area & Production of Horticulture Crops in India



Source: National Horticulture Board

India has established itself as the second largest producer of fruits and vegetables occupying 8 percent of the total cropping area. The total production of horticulture crop for the year 2005-06 has been 185.2 million metric tones out of which production of fruits has been estimated at 58740 thousand metric tonnes from an area of 5,510 thousand hectares and vegetables has been estimated at 1,09,050 thousand metric tonnes from an area of 7,164 thousand hectares during 2005-06.

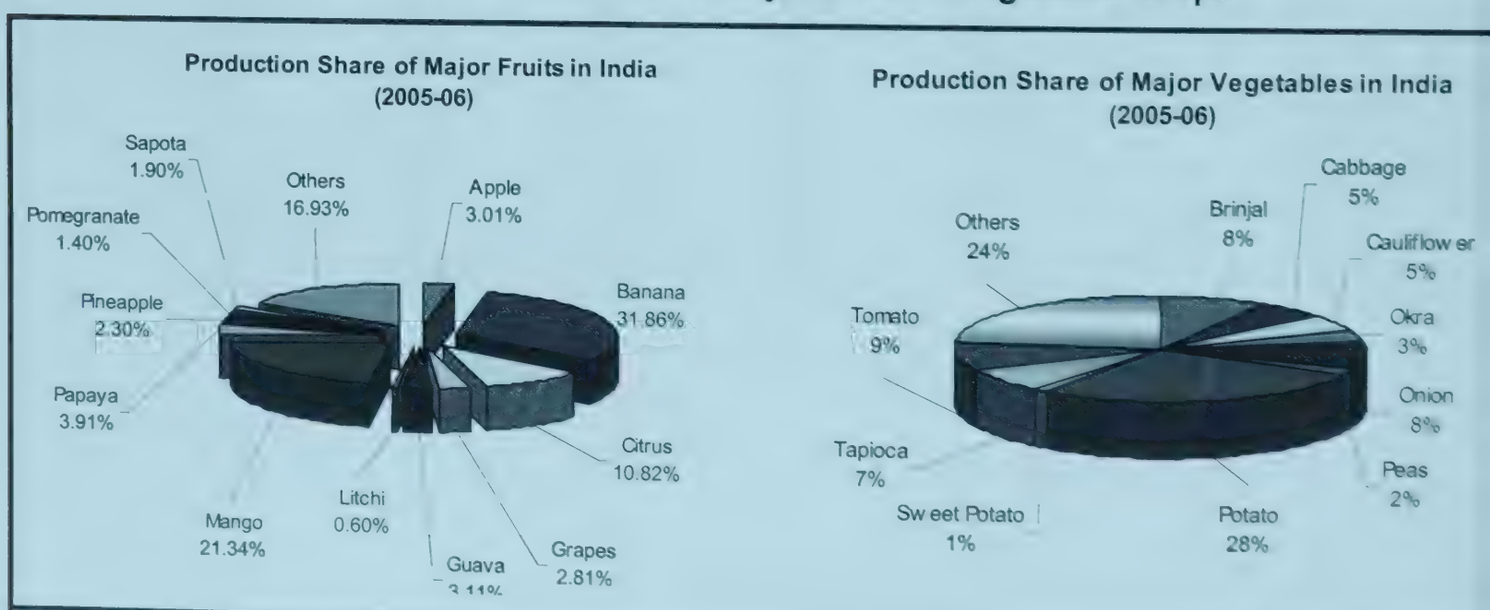
Figure 2 Product Composition



Source: National Horticulture Board

Among the various components that make up the horticulture basket fruits and vegetables occupy a major share to the tune of 31.74% fruits and 58.93% of vegetables rest of the portion is shared by nuts , flowers and plantation crops and so on.

Figure 3 Composition of Major Fruit & Vegetable Crops



Source: National Horticulture Board

Within the category of fruits, India is the largest producer of mango, banana, sapota and acid lime in the world. About 39.5 per cent of the world's mangoes and 11 per cent of world's bananas are produced in India. In grapes, India has the highest productivity in the world. India is next only to China in area and production of vegetables and occupies prime position in the production of cauliflower, second in onions and third in cabbage in the world.

India has also made noticeable advancement in the production of flowers. During 2006-07, the country produced 6, 69,000 metric tonnes of loose and 27.23 million cut flowers from an area of 1.40 lakh hectares.

Further the country has emerged as the largest producer, consumer and exporter of spices and spice products. The total estimated production of spices during 2005-06 was 4.86 million metric tones and the area covered was 3.20 million hectares. India is also largest producer and consumer of cashewnuts. The total production of plantation crops during 2005-06 is around 10.39 million metric tonnes from an area of 3.11 million hectares.

This brings us to the conclusion that in terms of production, India has been a forerunner in the international market. However, the country has not been able to sell its produce in the international market, thus having an insignificant presence in the international trade.

India' share in world trade of fruits and vegetables is about 1% which is very less as compared to the international standards. Despite producing 15% of the world's vegetables and 8% of fruits at very competitive costs of about 53% and 63% of average global prices, India's share in global fruits and vegetables trade has remained at only 1.7% and 0.5%, respectively. This is mainly due to the high prices and poor quality.

Export Statement (Qty. In MTs)

Commodity / Year			
	2004-05	**2005-06**	**2006-07**
Fresh Onions	870216.85	960507.32	1378373.17
Other Fresh Vegetables	190689.06	217280.54	275909.49
Walnuts	5851.16	5256.56	5062.06
Fresh Mangoes	53480.02	69606.6	79060.88
Fresh Grapes	39338.95	54049.87	85897.79
Other Fresh fruits	136954.26	158339.26	159569.71
Total	1296530.30	1465040.15	1983873.10

Source: APEDA

The exports statement show that the exports of fruit and vegetables have been increasing over a period of time. However, the total contribution in the world trade has not been significant. This is mainly due to availability of poor quality produce, post harvest losses which accounts for 8%-40% of the produce, absence of cold chain infrastructure and lengthy supply chain adding up to costs.

Post harvest losses, poor quality and high prices of horticulture produce are the result of poor post harvest handling and storage practices. Unlike most manufactured products, horticulture output requires additional care. Apart from the productivity and quality considerations at the production level, there are some necessary precautions that need to be taken care when horticulture produce is stored and transported. Absence of such cautious measures would have adverse effects on the quality of the produce, thus resulting in increased wastages and decreased market value.

Therefore, it is very important to develop techniques to reduce post harvest losses as well as to preserve or improve the quality, freshness and nutritional value of the produce until the products reach the consumers. Today, it is economical, to safeguard the crops that have been harvested, instead of trying to make up for losses through increase in production.

Further, it is observed that food production covers wide fields, as a chain from the cultivation to the final food market. Post harvest technology including selection, preservation, packaging and processing has contributed to the promotion of agricultural production through the improvement of farmer's income by raising the value of agricultural produce.

Along with this it is in the interest of the producers as well as the exporters to ensure that certain hygienic and other safety conditions are met. With an increase in the levels of health-safety awareness among the citizens of both developing and developed countries importance of food safety cannot be denied.

Recognizing the importance of the issues related to post harvest management, cold chain and food safety, Amity University in collaboration with Indo-US Science & Technology Forum, Ministry of Food Processing Industries and Global AgriSystem Pvt Ltd has compiled the work of eminent authors in the Handbook for ready reference and future consultation. We hope it will prove a valuable working aid to all those responsible for the storage and protection of harvested food crops.

Since humans are now using nearly all of the arable, ranch, and forested land on the planet, so preserving as much harvested food for as long as possible is our main hope of increasing food supplies in the future.

POST HARVEST TECHNOLOGY

Horticultural crops not only provide us with nutritional and healthy foods, but also generate a cash income to growers. Appropriate production practices, careful harvesting and proper packaging, storage and transport all contribute to the good produce quality. Once a crop is harvested, it is impossible to improve its quality. The horticultural crops, because of their high moisture content are inherently more liable to deteriorate especially under tropical conditions. Moreover, they are biologically active and carry out transpiration, respiration, ripening and other biochemical activities, which deteriorate the quality of the produce.

Losses during post harvest operations due to improper storage and handling are enormous and can range from 10-40 percent. Post harvest losses can occur in the field, in packing areas, in storage, during transportation and in the wholesale and retail market. Severe losses occur because of poor facilities, lack of know-how, poor management, market dysfunction or simply the carelessness of farmers. Proper storage conditions, temperature and humidity are needed to lengthen the storage life and maintain quality once the crop has been cooled to the optimum storage temperature.

Various technologies for reducing losses and improving the shelf life of fruits and vegetables are

Precooling

Good temperature management is the most effective way to reduce post-harvest losses and preserve the quality of fruits and vegetables. Products harvested from hot fields often carry field heat and have high rates of respiration. Rapid removal of field heat by precooling is so effective in quality preservation that this procedure is widely used for highly perishable fruits and vegetables. Currently used precooling methods include room cooling, forced-air cooling, water cooling, vacuum cooling and package icing.

Ice bank cooler is a new development in refrigeration with positive ventilation. In this system ice cool air is passed through the boxes containing horticultural produce. This facilitates quicker cooling and large amount of heat is removed in a relatively shorter period. The store maintains a temperature of 0.5-0.8°C and relative humidity of 98 percent.

Sanitation

Sanitation is of great concern to produce handlers, not only to protect produce against post harvest diseases, but also to protect consumers from food borne illnesses. E.coli 157:H7, *Salmonella, Chryptosporidium, Hepatitis and Cyclospera* are among the disease causing organisms that have been transferred via fresh fruits and vegetables. Use of a disinfectant in wash water can help to prevent both post harvest diseases and food borne illnesses.

Chlorine in the form of a sodium hypochlorite solution or as a dry powdered calcium hypochlorite can be used in hydro-cooling or wash water as a disinfectant.

Ozonation is another technology that can be used to sanitize produce. A naturally occurring molecule, ozone is a powerful disinfectant. Ozone not only kills whatever food borne pathogens might be present, it also destroys microbes responsible for spoilage. A basic system consists of an ozone generator, a monitor to gauge and adjust the levels of ozone being produced and a device to dissolve the ozone gas into the water.

Hydrogen peroxide can also be used as a disinfectant. Concentrations of 0.5% or less are effective for inhibiting development of post harvest decay caused by a number of fungi. Hydrogen peroxide has a low toxicity rating and is generally recognized as having little potential for environmental damage.

Grading

Essentially all fruits and vegetables sold in modern markets are graded and sized into two or more grades according to trade standards. Sophisticated marketing systems require precise grading standards for each kind of product. More primitive markets may not use written grade standards, but the products are sorted and sized to some extent.

Typical grading facilities in large packinghouses include dumpers and conveyors. Many products are sized according to their weight. Automated weight sizers of various capacities are used in packinghouses. Round or nearly round fruits are often sized according to their diameter, using automated chain or roller sizers or hand carried ring sizers. An inefficient sizing operation can also cause significant injuries.

Waxing

Food grade waxes are commonly applied to replace some of the natural waxes removed in the washing and cleaning operations to reduce water loss and to improve appearance. It also provides protection against decay organisms. Waxing may be done after grading and fungicides may be added to the wax. Application of wax and post harvest fungicides must be indicated on each container where the refrigerated storage facilities are not available Protective skin coating with wax is one of the methods for increasing the storage life of fresh fruits.

Packaging

The packaging of fruits and vegetables should protect them from injury and water loss, and be convenient for handling and marketing. Packages should also provide information about the product, including the grade, handling instructions, and appropriate storage temperatures when the product is on display. The cost of the packaging is important, including whether the container can be recycled or reused.

Packaging provides protection from physical damage during storage, transportation and marketing. There are variety of packages, packaging materials and inserts available.

There are two types of packaging. The first is when produce is packed in containers for transportation and wholesale. The second is when produce is packed into small retail units. Ideal containers for packing fruits and vegetables should be easy to handle, providing good protection from mechanical damage and should have adequate ventilation and should be

convenient for merchandising. They should also be inexpensive and easily degradable or recyclable. Fancy containers such as fiberboard boxes or wooden or plastic crates, are often used for high-value products. Inexpensive containers such as bamboo baskets or nylon net sacs are used for low-priced produce.

Prepackaging or consumer packaging generally provides additional protection for the products. It is also convenient for retailers as well as customers, and therefore adds value to produce. However, over-use of non-biodegradable plastic trays and wrapping materials, as often seen in modern supermarkets, which creates an extra burden of waste disposal and damages the environment.

A Perspective on Postharvest Horticulture (1978–2003)

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The goals of postharvest research and extension are to maintain quality and safety and minimize losses of horticultural crops and their products between production and consumption. Reduction of postharvest losses increases food availability to the growing human population, decreases the area needed for production, and conserves natural resources. Strategies for loss prevention include use of genotypes that have longer postharvest life, use of an integrated crop management system that results in good keeping quality, and use of proper postharvest handling systems that maintain quality and safety of the products. Thus, most horticulturists are involved to some extent in some aspects of postharvest horticulture, at least as consumers desiring fruit and vegetables with good flavor and nutritional quality and ornamentals with attractive appearance and long postproduction life.

Most accomplishments of postharvest horticulture have resulted from interdisciplinary, collaborative efforts among horticulturists and other plant biologists working with food scientists and engineers, marketing economists, consumer scientists, and other researchers and extensionists. Interactions among postharvest horticulturists and their colleagues from other disciplines are facilitated through the American Society for Horticultural Science (ASHS) Postharvest Working Group and the International Society for Horticultural Science (ISHS) Commission on Quality and Postharvest Horticulture. Also, many postharvest horticulturists participate regularly in ISHS International Postharvest Conferences, the Gordon Research Conferences on Postharvest Physiology, and the International Controlled Atmosphere Research Conferences, which have been held every 4 years since 1969. The Australasian Postharvest Conferences are held every 2 years in Australia or New Zealand. Results of postharvest research have been published in ASHS journals beginning with volume 9 of the *Proceedings of the American Society for Horticultural Science* published in 1913, as well as in a wide range of plant science, food science and technology, agricultural engineering, and other journals. A specialized abstracting journal titled *Postharvest News and Information* was initiated in 1990 and has been published bimonthly by CAB International. In 1991, Elsveir Science Ltd. initiated the journal *Postharvest Biology and Technology*, which has grown steadily (under the leadership of G.E. Hobson, R.P. Cavalieri, and I.B. Ferguson) in its ranking among journals and in frequency of publication to a monthly schedule in 2003. Published information covers the continuum from postharvest biology to technology of a broad range of horticultural crops and their products.

When ASHS celebrated its 75th anniversary in 1978, Professor Don Dewey, Michigan State University, reviewed the accomplishments of postharvest horticulture since 1903 under the title "Three Remarkable Generations of Postharvest Horticulture" (Dewey, 1979). Interest in postharvest horticulture within ASHS began early and expanded quickly as evidenced by the number of papers focused on postharvest physiology and quality that were published in the ASHS *Proceedings*. He reviewed the history of identifying ethylene as a gas that influences plant growth and development, fruit ripening, and senescence of harvested plant organs. He predicted correctly that "there seems little doubt but that ethylene will play a major role in our future work and publications." He also identified postharvest disorders (physiological and pathological) as an important research area that received much attention from postharvest horticulturists between 1903 and 1978. Identifying preharvest and postharvest factors that influence incidence and severity of physiological disorders remained an active research area during the past 25 years (Ferguson et al., 1999; Hodges, 2003). Important discoveries have concerned the nature of chilling injury (Saltveit, 2000; Wang, 1990), the control of storage scald on apple, the cause of bent-neck in cut roses, and the role of calcium (Bangerth, 1979) or other elements in tomato blossom-end rot, tipburn in lettuce, and flesh breakdown in apple. However, in most cases the underlying molecular and physiological causes are yet to be discovered. Dewey (1979) concluded his presentation by challenging horticulturists to make postharvest research a more sophisticated and far reaching science than it was in 1978. In this presentation I will provide a brief review of developments in postharvest horticulture during the past 25 years which represent the fourth remarkable generation of postharvest horticulture.

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POSTHARVEST BIOLOGY

Together, Kidd and West's discovery of the climacteric and Blackman's monumental studies of respiration in apples established the basis of modern postharvest physiology (Laties, 1995). Professor Jacob Biale and his students contributed greatly to the development of postharvest physiology research during the 1950s, 1960s, and beyond. Romani (1991), in an excellent feature article published in *HortScience*, provided his perspective on postharvest physiology and biochemistry during 4 decades (1950 to 1989) and future outlook for the 1990s. He concluded that "whatever its future directions, research in postharvest physiology and biochemistry promises to be an increasingly well-delineated field of scientific inquiry." Sharples (1990), King and O'Donoghue (1995), and Mattoo and Handa (2001) presented their perspectives of postharvest biology research.

Saltveit et al. (1998) reviewed the history of the discovery of ethylene as a plant growth substance, the identification of 1-aminocyclopropane-1-carboxylic acid (ACC) as the precursor of ethylene by Adams and Yang (1979) and Lürssen et al. (1979), and the recognition of ACC synthase and ACC oxidase as key enzymes of ethylene biosynthesis. They concluded that "while great advances had been made with the traditional techniques of physiology and biochemistry, further elucidation of ethylene biosynthesis and action hinged on using the modern techniques of molecular biology and genetic engineering." Breakthroughs in understanding ethylene signal transduction came from pursuing a genetic approach in *Arabidopsis thaliana* (Bleeker, 1999). A family of ETR1-like receptors interact with CTR1 to express ethylene response pathways while ethylene binding inhibits this activity. A summary of factors that influence ethylene biosynthesis and action is presented in Fig. 1.

Molecular and genetic analysis of fruit development, and especially ripening of fleshy fruit, has resulted in significant gains in knowledge over recent years about ethylene biosynthesis and response, cell wall metabolism, and environmental factors that impact ripening (Grierson, 1987; Seymour et al., 1993; Giovannoni, 2001). The isolation of fruit ripening-related genes has resulted not only in tools for studying the direct effects of specific gene products on ripening but also in opportunities to isolate and study gene regulatory elements that may illuminate regulatory mechanisms (Giovannoni, 2001).

Biotechnology is a tool that can be used, in an interdisciplinary approach, to address some of the concerns about quality attributes and

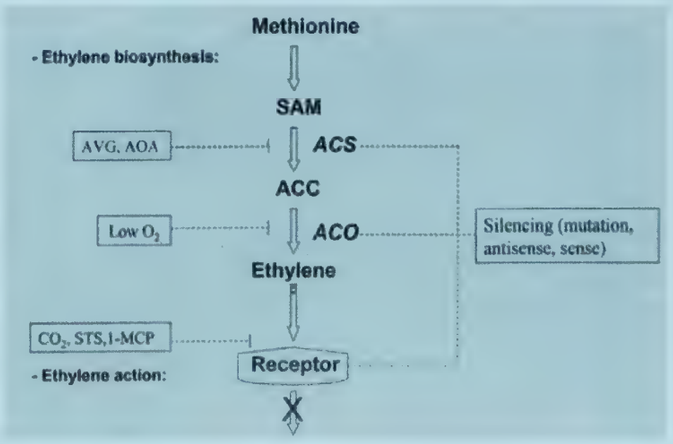

Fig. 1. A summary of factors that influence ethylene biosynthesis and action (courtesy of Bruno Defilippi).

the biological causes of deterioration of harvested produce (King and O'Donoghue, 1995; Mattoo and Handa, 2001). Kader (2002b) proposed that priority should be given to the following goals: 1) to attain and maintain good flavor and nutritional quality to meet consumer demands and encourage greater consumption of fresh fruit and vegetables, 2) to introduce resistance to physiological disorders and/or decay-causing pathogens to reduce use of chemicals, and 3) to modify surface structure and/or composition of some commodities to reduce their microbial contamination potential.

The challenge to molecular biologists is that many of the desired improvements require manipulation of more than one gene, and in some cases target genes have not yet been identified.

Oxidative stress occurs when the generation of active oxygen species (e.g., H_2O_2 and –OH) exceeds the capacity of the organism to maintain redox homeostasis and results in physiological disorders (Hodges, 2003.). Antioxidants that protect plant products against stress also play an important role in protecting humans against heart disease, cancer, and other chronic and degenerative diseases (Hyson, 2002; Prior and Cao, 2000). Many postharvest researchers are involved in evaluating antioxidant activities and phytochemical constituents in various fruit and vegetables as affected by cultivar, production practices, and postharvest handling procedures (Buescher et al., 1999; Goldman et al., 1999; Kalt, 2001; Perkins-Veazie and Collins, 2001). This will likely continue to be an active research area in the future.

POSTHARVEST TECHNOLOGY

Research aimed at identifying maturity and quality indices for a broad range of horticultural crops was continued during the past 25 years. Many nondestructive methods of quality evaluation have been developed (Abbott et al., 1997). More attention is focused on flavor quality (Mattheis and Fellman, 1999). Optimal postharvest handling conditions for more than 100 commodities were defined and published in a revised edition of *USDA Handbook No. 66* (Hardenburg et al., 1986), which was recently revised again with contributions by 90 authors (Gross et al., 2002). Other books that provided relevant information on postharvest biology and technology of horticultural crops include those by Ryall and Lipton (1979), Ryall and Pentzer (1982), Kays (1991), Seymour et al. (1993), Shewfelt and Prussia (1993), Thompson (1996), Wills et al. (1998), Bartz and Brecht (2002), Knee (2002), Kader (2002a), and Kitinoja and Kader (2002).

Research on how to maintain quality and safety of fresh-cut fruit and vegetables increased greatly during the past 15 years in response to commercial development of value-added, ready-to-eat products. Strategies for delaying browning and softening of wounded plant tissues and for maintaining their safety by minimizing microbial growth have been developed (Gorny, 2002; Lamikanra, 2002), but more research is needed to enable extension of postcutting life based on flavor and nutritional quality.

Providing the optimal ranges of temperature and relative humidity (RH) is the most important tool for maintaining quality and safety of intact and fresh-cut fruit and vegetables, fresh herbs, and ornamental crops (Cantwell and Reid, 1993; Gross et al., 2002; International Institute of Refrigeration, 1993 and 1995; Kader, 2002a; Nell and Reid, 2000; Thompson et al., 1998; Internet sites: http://postharvest.ucdavis.edu; http://www.postharvest.com.au; www.fao.org/inpho). There is a continuing trend toward increased precision in temperature and relative humidity (RH) management to provide the optimum environment for fresh produce during cooling, storage, and transport. Precision temperature management tools, including time-temperature monitors, are becoming more common in cooling and storage facilities. Several manufacturers have developed self-contained temperature and RH monitors and recorders, which are small and can be packed in a box with the product. Data are read by connecting these units to a personal computer with the appropriate software provided by the manufacturer. Infrared thermometers are used to measure surface temperature of products from a distance in various locations within storage facilities. Electronic thermometers (with very thin, strong probes for fast response) are used for measuring product temperature during cooling, storage, and transport operations. Recent surveys indicate an improvement in temperature maintenance within refrigerated display cabinets used in retail stores with an overall mean of about 5°C. There is no substitute to maintaining the cold chain throughout the postharvest handling system (Fig. 2) for ensuring quality and safety of horticultural perishables. All other postharvest technology procedures are supplements to proper temperature management (Fig.3).

Continued research on technologies to reduce water loss included use of polymeric films (Ben Yehoshua, 1985) and surface coatings (Amarante and Banks, 2001; Baldwin, 1994). The use of polymeric films for packaging produce and their application in modified atmosphere packaging (MAP) systems at the pallet, shipping container (plastic liner), and consumer

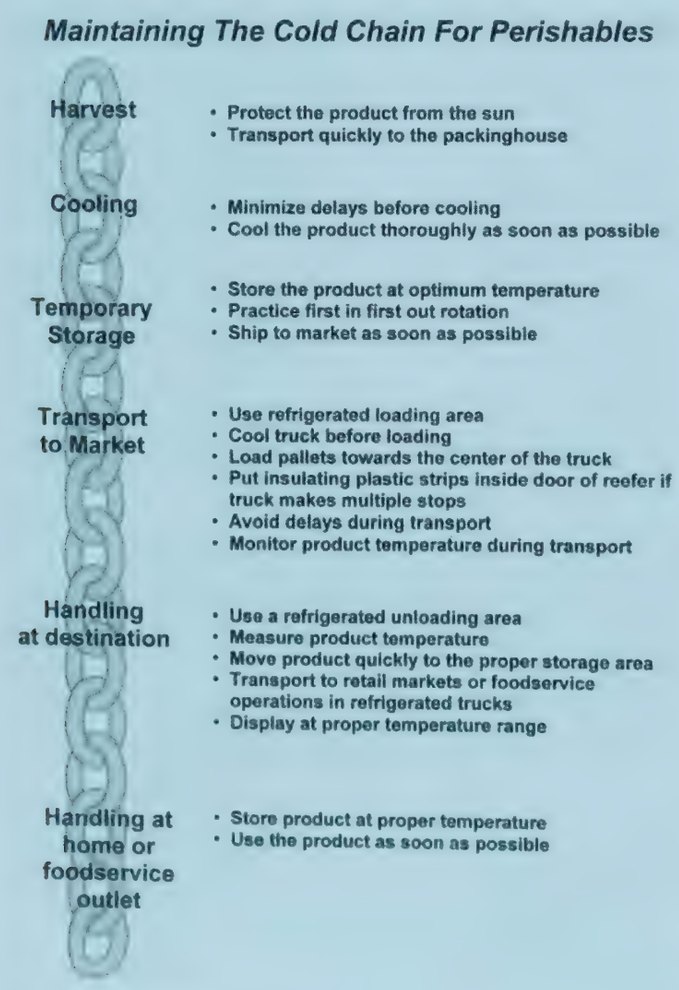

Fig. 2. Actions needed to maintain the cold chain throughout the postharvest handling system for perishable horticultural crops.

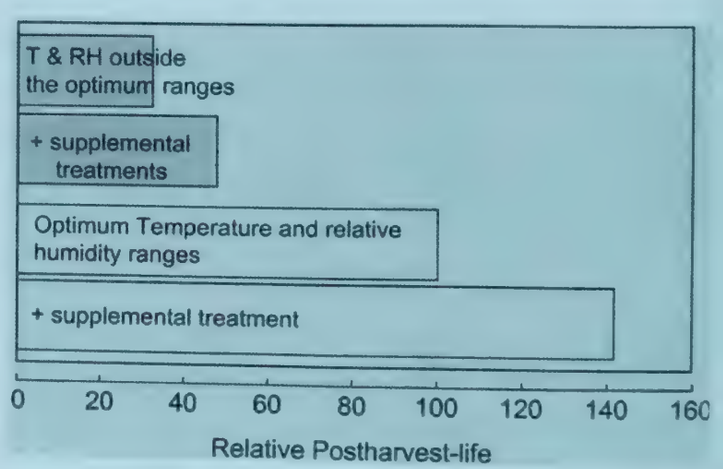

Fig. 3. Providing optimal ranges of temperature and relative humidity is the most effective method for extending postharvest life. All other technologies (such as waxing, postharvest fungicides, sprout inhibitors, controlled or modified atmospheres, ethylene exclusion or scrubbing, and 1-MCP treatments) are supplemental and extend postharvest life by only 25% to 40%.

package levels continues to increase (Beaudry, 2000; Kader et al., 1989; Lange, 2000; Watkins, 2000). MAP (usually to maintain 2% to 4% O_2 and 8% to 12% CO_2) is widely used in extending the shelf life of fresh-cut vegetable and fruit products. Use of absorbers of ethylene, carbon dioxide, oxygen, and/or water vapor as part of MAP is increasing. Although much research has been done on use of surface coatings to modify the internal atmosphere within the commodity, commercial applications are still very limited due to the variability of the commodity's gas diffusion characteristics and the stability and thickness of the coating.

Several refinements in CA storage technology have been made in recent years (Calderon and Barkai-Golan, 1990). These include the creation of nitrogen on demand by separation from compressed air using molecular sieve beds or membrane systems (Dilley, 1990), use of low (0.7% to 1.5%) O_2 concentrations that can be accurately monitored and controlled, rapid establishment of CA, ethylene-free CA, programmed (or sequential) CA (such as storage in 1% O_2 for 2 to 6 weeks followed by storage in 2% to 3% O_2 for the remainder of the storage period), and dynamic CA where levels of O_2 and CO_2 are modified as needed based on monitoring some attributes or produce quality, such as ethanol concentration and chlorophyll fluorescence.

The use of CA in refrigerated marine containers continues to benefit from technological and scientific developments. CA transport is used to continue the CA chain for some commodities (such as apples, pears, and kiwifruit) that had been stored in CA since harvest. CA transport of bananas permits their harvest at a more fully mature stage resulting in higher yield. CA transport of avocados facilitates use of a lower temperature (5 °C) than if shipped in air because CA ameliorates chilling injury symptoms. CA combined with precision temperature management may allow nonchemical insect control in some commodities (Mitcham, 2003) for markets that have restrictions against pests endemic to exporting countries and for markets that prefer organic produce.

At the commercial level, CA is most widely applied during the storage and transport of apples and pears. It is also applied to a lesser extent on asparagus, broccoli, cantaloupes, kiwifruit, avocados, persimmons, pomegranates, and nuts and dried fruit. Atmospheric modification during transport is used on apples, avocados, bananas, blueberries, cherries, figs, kiwifruit, mangoes, nectarines, peaches, pears, plums, raspberries, and strawberries. Continued technological developments in the future to provide CA during transport and storage at reasonable cost (positive benefit–cost ratio) are essential to expanding its application on fresh fruit and vegetables.

The promotion of senescence in harvested horticultural crops by ethylene (>0.1ppm) results in acceleration of deterioration and reduced postharvest life. Ethylene accelerates chlorophyll degradation causing yellowing of green tissues, thus reducing quality of leafy, floral, and immature fruit and vegetables and foliage ornamentals. Ethylene induces abscission of leaves and flowers, softening of fruit, and several physiological disorders (Abeles et al., 1992; Reid, 1995). Ethylene may increase decay development of some fruit by accelerating their senescence and softening, and by inhibiting the formation of antifungal compounds in the host tissue. In some cases, ethylene may stimulate growth of fungi such as *Botrytis cineria* on strawberries and *Penicillium italicum* on oranges (Sommer, 1989).

Low temperatures, controlled or modified atmospheres (Kader, 1986a), treatment of ornamentals with silver thiosulfate, and ethylene avoidance and/or scrubbing techniques are used to reduce ethylene damage. The discovery of the ethylene action inhibitor, 1-methylcyclopropene (1-MCP), in the early 1990s (Sisler and Blankenship, 1996) is a major breakthrough. Since 1999, 1-MCP has been used under the trade name Ethylbloc for treatment of cut flowers and other ornamental crops to render them insensitive to ethylene action and associated detrimental effects. In July 2002, 1-MCP (under the trade name SmartFresh) at concentrations up to 1 ppm was approved by the U.S. Environmental Protection Agency for use on apples, apricots, avocados, kiwifruit, mangoes, nectarines, papayas, peaches, pears, persimmons, plums, and tomatoes. The first commercial application has been on apples to retard their softening and scald development and extend their postharvest life. As more research is completed, the use of 1-MCP will no doubt be extended to several other commodities in the future (Blankenship and Dole, 2003).

Currently used treatments for decay control include 1) heat treatments (Lurie, 1998; Paull and Chen, 2000) such as dipping mangoes for 5 min in 50 °C water to reduce subsequent development of anthracnose; 2) use of postharvest fungicides such as imazalil and/or thiabendazole on citrus fruit; 3) use of biological control agents (Wilson and Wisniewski, 1989) such as bio-Save (*Pseudomonas syringae*) and Aspire (*Candida olephila*) alone or in combination with fungicides at lower concentrations on citrus fruit; 4) use of growth regulators such as gibberellic acid or 2, 4-D to delay senescence of citrus fruit; 5) use of 15% to 20% CO_2 in air or 5% O_2 on strawberries, cane berries, figs, and pomegranates; and 6) use of SO_2 fumigation (100 ppm for 1 h) on grapes.

A large number of insects can be carried by fresh fruit, vegetables, and flowers during postharvest handling. Many of these insect species, especially the fruit flies of the family Tephritidae (e.g., mediterranean fruit fly, oriental fruit fly, mexican fruit fly, caribbean fruit fly), can seriously disrupt trade among countries. Continuing globalization of marketing fresh produce will be facilitated by use of acceptable disinfestation treatments. Selection of the best treatment for each commodity will depend on the comparative cost and the efficacy of that treatment against the insects of concern with the least potential for damaging the host (Paull and Armstrong, 1994; Sharp and Hallman, 1994). Much of the research during the past 15 years has been focused on finding alternatives to methyl bromide fumigation.

Currently approved quarantine treatments include certification of insect-free areas, use of chemicals (e.g., methyl bromide, phosphine, hydrogen cyanide), cold treatments, heat treatments, irradiation, and some combinations of these treatments, such as methyl bromide fumigation followed by cold treatment. The potential for additional treatments, such as new fumigants (carbonyl sulfide, methyl iodide, sulfuryl fluoride), insecticidal atmospheres (<0.5% O_2 and/or 40% to 60% CO_2) alone on or in combination with heat treatments, and ultraviolet radiation, is being investigated. Each of these treatments is usable on a limited number of commodities but causes phytotoxic effects on others.

Most insects are sterilized when subjected to irradiation doses ranging between 50 and 750 Gy. The actual dosage required varies in accordance with the species and its stage of development. An irradiation dose of 250 Gy has been approved for certain fresh commodities, such as lychees, mangoes, and papayas by U.S. quarantine authorities in light of its efficacy in preventing adult emergence of tropical fruit flies. Most fresh fruit and vegetables will tolerate irradiation dose of 250 Gy with minimal detrimental effects on quality. At doses above 250 Gy and up to 1000 Gy (the maximum allowed as of 2003), damage can be sustained by some commodities (Kader, 1986b). Fruit, in general, are more tolerant to the expected dose range (250 to 500 Gy absorbed by fruit on the inside vs. those on the outside of the pallet) than nonfruit vegetables and cut flowers. Detrimental effects on fresh produce may include loss of green color (yellowing), abscission of leaves and petals, tissue discoloration, and uneven ripening.

FOOD SAFETY AND SECURITY

Over the past few years, food safety has become and continues to be the number one concern of the fresh produce industry (Bracket, 1999; Kitinoja and Gorny, 1999). The U.S. Food and Drug Administration (USFDA) published in October 1998 a *Guide to Minimize Microbial food Safety Hazards for Fresh Fruit and Vegetables*. This guide is based on the general principle that prevention of microbial contamination of fresh produce is favored over reliance on corrective actions once contamination has occurred. A manual for trainers, titled *Improving the Safety and Quality of Fresh Fruit and Vegetables*, was published by the USFDA in November 2002 to provide uniform, broad-based scientific and practical information on the safe production, handling, storage, and transport of fresh produce. It is available electronically (in English and Spanish) at http://www.jifsan.umd.edu/gaps.html. Another useful website is the University of California's Good Agricultural Practices available at http://ucgaps.ucdavis.edu.

Clean, disinfected water is required to minimize the potential transmission of pathogens from water to produce, from healthy to infected produce within a single lot, and from one lot to another over time. Waterborne microorganism, including postharvest plant pathogens and agents of human illness, can be rapidly acquired and taken up on plant surfaces. Natural plant surface contours, natural openings, harvest and trimming wounds, and scuffing can be points of entry as well as provide

safe harbor for microbes. In these protected sites, microbes are largely unaffected by common or permitted doses of postharvest water sanitizing treatments (e.g., chlorine compounds, ozone, and hydrogen peroxide). It is essential therefore, that an adequate concentration of sanitizer is maintained in water to kill microbes before they attach or become internalized in product. This is important in some preharvest water uses (such as spraying pesticides or growth regulators) and in all postharvest procedures involving water, including washing, cooling, water-mediated transport (flumes), and postharvest drenching with calcium chloride or other chemicals.

The emphasis of current research on produce safety is on developing reliable and quick detection methods for human pathogens, improved efficacy of water disinfection methods, and developing methods for reducing microbial load on intact and fresh-cut fruit and vegetables. Other aspects of produce safety include assuring that the residues of pesticides are within the legal limits and handling conditions that may lead to contamination with mycotoxins are avoided.

The national organic standards in the U.S. became effective in October 2002 and are available electronically at http://www.ams.usda.gov/nop/. Organic produce must be handled separately from conventionally grown produce to avoid cross-contamination with pesticide residues. Water disinfection treatments, such as chlorination and ozonizations, can be used on organic produce to minimize the potential for microbial contamination.

On 19 Mar. 2003, The U.S. Food and Drug Administration (USFDA) released food security guidance documents for food producers, processors, and transporters. These documents are available electronically at http://www.cfsan.fda.gov/~dms/secguid6.html and are voluntary recommendations from USFDA—not mandatory regulations. The goal is to help operators of food handling facilities identify preventive measures to minimize the security risks to their products.

THE VALUE OF POSTHARVEST RESEARCH AND EXTENSION

Postharvest losses vary greatly among commodities and production areas and seasons. In the U.S., the losses of fresh fruit and vegetables are estimated to range from 2% to 23%, depending on the commodity, with an overall average of about 12% losses between production and consumption sites (Cappellini and Ceponis, 1984; Harvey, 1978). Kantor et al. (1997) estimated the U.S. total retail, foodservice, and consumer food losses in 1995 to be 23% of fruit and 25% of vegetables. Fresh fruit and vegetables accounted for nearly 20% of consumer and foodservice losses, which are due to product deterioration, excess perishable products that are discarded, and plate waste (food not consumed by the purchaser). The latter is often due to consumer dissatisfaction with product quality, especially flavor. Estimates of postharvest losses in developing countries vary greatly from 1% to 50% or even higher (FAO, 1981; National Academy of Sciences, 1978). Mrema and Rolle (2002) reported that priorities within the postharvest sector of developing countries have evolved from a primarily technical focus geared toward the reduction of losses to a more holistic approach designed to link on-farm activities to processing, marketing, and distribution. Despite this evolution in trends, fundamental problems and concerns of the sector have remained relatively unchanged, with high postharvest losses, poor marketing systems, weak research and development capacity, and inadequacies in policies, infrastructure, and information exchange cited as major constraints within the sector in developing regions of the world (Mrema and Rolle, 2002). Similar conclusions were reached by the participants in a workshop on Postharvest Technologies for Developing Countries that was organized by Errol W. Hewett during the 26th International Horticultural Congress in Toronto, Canada (August 2002).

Although minimizing postharvest losses of already produced food is more sustainable than increasing production to compensate for these losses, less than 5% of the funding of agricultural research is allocated to postharvest research areas. This situation must be changed to increase the role of postharvest loss reduction in meeting world food needs. Goletti and Wolff (1999) stated that "while research on the improvement of agricultural production has received considerable attention and funding, until recently postharvest activities have not attracted much attention from international research organizations (CGIAR, FAO, ACIAR, IDRC, CTZ, CIRAD, NRI, USAID)." They identified the following reasons to justify

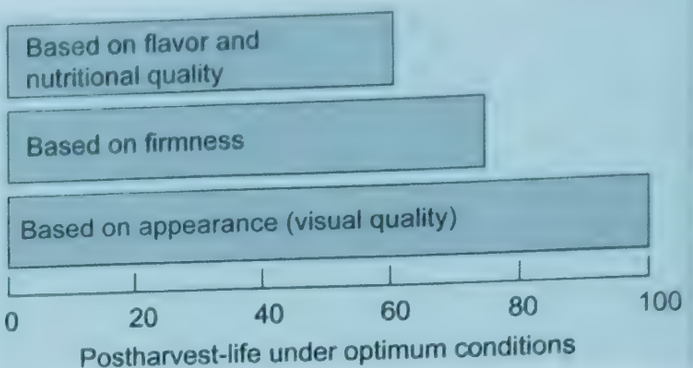

Fig. 4. Postharvest life based on flavor and nutritional quality is shorter than postharvest life based on firmness of appearance of most fresh fruit and vegetables.

an increased commitment to postharvest research by the international agricultural system: 1) high internal rates of return, 2) international public good character, 3) effect on poverty, 4) effect on food security and health, and 5) effect on sustainable use of resources. Goletti and Wolff (1999) concluded that "As the significant contribution of postharvest research to CGIAR goals such as poverty reduction, food security and sustainability becomes clear, and in the light of high rates of return, the very skewed allocation of funds to production versus postharvest topics cannot be justified. Since, so far, relatively little has been invested in postharvest research, there is potential for large impacts as constraints and bottlenecks are removed. It would thus be desirable to re-examine current funding priorities and to allocate a larger proportion of resources to the postharvest area."

FUTURE OUTLOOK

Remarkable progress in postharvest biology and technology of horticultural crops has been achieved during the past 25 years through collaborative and interdisciplinary research and development efforts of the public and private sectors, especially in developed countries. Achieving similar progress in developing countries requires application of current knowledge to improve the handling systems of horticultural perishables and overcoming the socioeconomic constraints that have prevented such progress.

Devoting more attention to flavor and nutritional quality of fruit and vegetables is strongly recommended. This should include identification of the reasons for postharvest life based on flavor being shorter than postharvest life based on appearance (Fig. 4), selection of cultivars with flavor life that is close to appearance life, and modification of current postharvest handling recommendations based on maximizing flavor life potential.

New cultivars of fruit and vegetable with better flavor and nutritional quality will be developed using biotechnology and/or plant breeding methods. This will contribute to increased consumption and consequently healthier diets for consumers. Educational efforts such as those of the Produce for Better Health Foundation (www.5aday.org) and the National Cancer Institute (www.5aday.gov) must be expanded to achieve their goals.

Innovative technologies for maintaining optimal temperature and relative humidity, delaying losses of flavor and nutritional quality by supplemental treatments, and ensuring safety will continue to be developed through collaboration between public and private organizations.

Worldwide availability of both conventially and organically grown horticultural crops will continue to increase in terms of the number of species and cultivars as well as their expanded season of availability with production in northern and southern hemisphere countries. Continued consolidation and vertical integration among producers and marketers will characterize the global marketing systems for fresh produce. This will facilitate collaboration among producers and marketers from various production areas to limit the marketing period on the basis of availability of superior flavor quality products from each production area. Postharvest biologists and technologists will play a key role in shaping the future of postharvest horticulture as they have done in the past century.

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Increasing Food Availability by Reducing Postharvest Losses of Fresh Produce

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Keywords: deterioration factors, fruits, loss estimation, socioeconomic factors, vegetables

Abstract

Qualitative losses (such as loss of caloric and nutritive value, loss of acceptability by consumers, and loss of edibility) are more difficult to measure than quantitative losses of fresh fruits and vegetables. While reduction of quantitative losses is a higher priority than qualitative losses in developing countries, the opposite is true in developed countries where consumer dissatisfaction with produce quality results in a greater percentage of the total postharvet losses. Providing consumers with fruits and vegetables that taste good can greatly increase their consumption of the recommended minimum of five servings per day for better health. Development of new cultivars with better flavor and nutritional quality plus adequate productivity should be given high priority in all countries. Strategies for reducing postharvest losses in developing countries include: (1) Application of current knowledge to improve the handling systems (especially packaging and cold chain maintenance) of horticultural perishables and assure their quality and safety; (2) Overcoming the socioeconomic constraints, such as inadequacies of infrastructure, poor marketing systems, and weak R&D capacity; and (3) Encouraging consolidation and vertical integration among producers and marketers of horticultural crops.

ESTIMATION OF POSTHARVEST LOSSES

Both quantitative and qualitative losses occur in horticultural crops between harvest and consumption. Our goal is to minimize these losses, and to do so we must: 1) understand the biological and environmental factors involved in postharvest deterioration, and 2) use the appropriate postharvest technology procedures that will slow down deterioration and maintain quality and safety of the commodities. Qualitative losses, such as loss in edibility, nutritional quality, caloric value, and consumer acceptability of the products, are much more difficult to assess than quantitative losses. Standards of quality and consumer preferences and purchasing power vary greatly among countries and cultures. For example, elimination of defects from a given commodity before marketing is much less rigorous in developing countries than in developed countries. This, however, is not necessarily bad, because appearance quality is often over-emphasized in developed countries.

Postharvest losses vary greatly among commodities and production areas and seasons. In the United States, the losses of fresh fruits and vegetables are estimated to range from 2% to 23%, depending on the commodity, with an overall average of about 12% losses between production and consumption sites (Cappellini and Ceponis, 1984; Harvey, 1978). Kantor et al (1997) estimated the U.S. total retail, foodservice, and consumer food losses in 1995 to be 23% of fruits and 25% of vegetables. Fresh fruits and vegetables accounted for nearly 20% of consumer and foodservice losses, which are due to product deterioration, excess perishable products that are discarded, and plate waste (food not consumed by the purchaser). The latter is often due to consumer dissatisfaction with product quality, especially flavor. Estimates of postharvest losses in developing countries vary greatly from 1 to 50% or even higher (National Academy of Sciences,

1978). Only a few estimates based on actual surveys have been published (Table 1).

Based on the limited data available and my own experience, I estimate that worldwide about one third of all fruits and vegetables produced are never consumed by humans. The general difference between developed and developing countries is that more of the losses occur between production and retail sites in developing than in developed countries (Table 2). I realize that many colleagues will disagree with my estimates and argue that losses in developing countries are much higher, but the only way to settle this argument is to collect data on postharvest losses. With the introduction of Universal Price Codes (UPC) for produce in the U.S. and other countries, we now have an opportunity to obtain detailed information about postharvest losses of produce items at the wholesale and retail levels. However, it is not clear at this time whether the major retailers will be willing to share such data. In any case, I believe that most people agree that more can and should be done to reduce postharvest losses in all countries. It is not economical or practical to aim for 0% losses, but an acceptable loss level for each commodity-production area and season combination can be identified on the basis of cost-benefit analysis (return on investment evaluations).

BIOLOGICAL AND ENVIRONMENTAL CAUSES OF LOSSES

Biological (internal) causes of deterioration include respiration rate, ethylene production and action, rates of compositional changes (associated with color, texture, flavor, and nutritive value), mechanical injuries, water stress, sprouting and rooting, physiological disorders, and pathological breakdown. The rate of biological deterioration depends on several environmental (external) factors, including temperature, relative humidity, air velocity, and atmospheric composition (concentrations of oxygen, carbon dioxide, and ethylene), and sanitation procedures. All these factors have been discussed by numerous authors (Bartz and Brecht, 2002; Bourne, 1977; Bourne, 1983; Coursey 1983; FAO, 1981; FAO, 1989; Gross et al, 2002; Harvey, 1987; Kader, 1983; Kader, 2002; Kitinoja and Gorny, 1999; Musa, 1984; Tindall and Proctor, 1980).

SOCIOECONOMIC FACTORS

Although the biological and environmental factors that contribute to postharvest losses are well understood and many technologies have been developed to reduce these losses, they have not been implemented due to one or more of the following socioeconomic factors (Kader, 1983).

Inadequate Marketing Systems

Growers can produce large quantities of good-quality fruits, ornamentals, and vegetables, but, if they do not have a dependable, fast, and equitable means of getting such commodities to the consumer, losses will be extensive. This problem exists in many locations within developing countries. It is accentuated by lack of communication between producers and receivers, and lack of market information.

Marketing cooperatives should be encouraged among producers of major commodities in important production areas. Such organizations are especially needed in developing countries because of the relatively small farm size. Advantages of marketing cooperatives include: providing central accumulation points for the harvested commodity, purchasing harvesting and packing supplies and materials in quantity, providing for proper preparation for market and storage when needed, facilitating transportation to the markets, and acting as a common selling unit for the members, coordinating the marketing program, and distributing profits equitable.

Alternative distribution systems, such as direct selling to the consumer (roadside stands, produce markets in cities, local farmers' market in the countryside, etc.) should be encouraged. Production should be maintained as close to the major population centers as possible to minimize transportation costs.

Wholesale markets in most of the developing countries are in desperate need of improvement in terms of facilities and sanitation. These are overcrowded, unsanitary, and

lack adequate facilities for loading, unloading, ripening, consumer packaging, and temporary storage. In several countries, there are plans to build better wholesale marketing facilities, but their implementation has been delayed more because of social and political than financial considerations.

Inadequate Transportation Facilities

In most developing countries, roads are not adequate for proper transport of horticultural crops. Also, transport vehicles and other modes, especially those suited for fresh horticultural perishables, are in short supply. This is true whether for local marketing or export to other countries. The majority of producers have small holdings and cannot afford to own their own transport vehicles. In a few cases, marketing organizations and cooperatives have been able to acquire transport vehicles, but they cannot do much about poor road conditions.

Government Regulations and Legislations

The degree of governmental controls, especially on wholesale and retail prices of fresh fruits and vegetables, varies from one country to another. In many cases, price controls are counter-productive. Although intended for consumer protection, such regulations encourage fraud and provide no incentive for producing high-quality produce or for postharvest quality maintenance. On the other hand, regulations covering proper handling procedures and public health aspects (food safety issues) during marketing are, if enforced properly, very important to the consumer.

Unavailability of Needed Tools and Equipment

Even if growers and handlers of fresh horticultural crops were convinced of the merits of using some special tools and/or equipment in harvesting and postharvest handling, they most likely will not be able to find them in the domestic market. This is true of harvesting aids; containers; equipment for cleaning, waxing, and packing; and cooling facilities. Most of the tools are neither manufactured locally nor imported in sufficient quantity to meet demand. Various governmental regulations in some countries do not permit direct importation by producers of their needs. It is imperative that the tools that will enable handlers to use recommended technology for a given situation be available for them to use. In many cases, such tools can be manufactured locally at much lower cost than those imported.

Lack of Information

The human element in postharvest handling of horticultural commodities is extremely important. Most handlers involved directly in harvesting, packaging, transporting, and marketing in developing countries have limited or no appreciation for the need for, or how, to maintain quality. An effective and far-reaching educational (extension) program on these aspects is needed critically now and will continue to be essential in the future. The availability of needed information on the Internet (numerous websites including: http://www.fao.org/inpho; http://www.postharvest.com.au; http://postharvest.ucdavis.edu; http://www.postharvest.ifas.ufl.edu; and www.postharvest.org) is an important step in the right direction, especially with the expanded access to the Internet worldwide.

Poor Maintenance

In many developing countries, some good facilities that were built a few years ago are currently "out of order" or not functioning properly because of lack of maintenance and unavailability of spare parts. This problem is especially true of public-sector facilities. Any new project should include in its plan adequate funds for maintenance to ensure its success and extended usefulness.

STRATEGIES FOR REDUCING POSTHARVEST LOSSES

A systematic analysis of each commodity production and handling system is the logical first step in identifying an appropriate strategy for reducing postharvest losses (Bell et al., 1999; Kitinoja and Gorny, 1999; LaGra, 1990). Also, a cost-benefit analysis to determine the return on investment in the recommended postharvest technologies is essential (for information on how to conduct such analyses, see Kitinoja and Gorny, 1999). It is important to select the technologies that are appropriate for the size of each postharvest enterprise (Clarke, 1994; Kitinoja and Gorny, 1999; Kitinoja and Kader, 1995; Persson, 1986). Marketing companies and cooperatives are essential for handling produce and reducing postharvest losses by providing facilities for accumulating, preparing and transporting produce to markets; by coordinating marketing activities; and by distributing profits equitably to members.

Mrema and Rolle (2002) indicated an evolution of priorities within the postharvest sector of developing countries from a primarily technical focus geared towards the reduction of losses, to a more holistic approach designed to link on-farm activities to processing, marketing, and distribution. However, the major constraints continue to be high postharvest losses, poor marketing systems, weak research and development capacity, and inadequacies in policies, infrastructure, and information exchange. The Agricultural and Food Engineering Technologies Service of FAO, in collaboration with the Global Forum for Agricultural Research (GFAR) and the Global Post-Harvest Forum (PhAction) recently embarked upon the development of a new global post-harvest initiative geared toward addressing the challenges faced by the sector in developing countries (Heyes, 2003; Rolle and Mazaud, 2003). Goletti (2003) listed the most relevant issues for developing countries as follows: the need for a regulatory framework that promotes growth while safe-guarding welfare; for adequate market information to be given to all participants involved; for further investment in postharvest research; and for participation in international agreements that promote trade and food safety.

VALUE OF POSTHAVEST RESEARCH AND DEVELOPMENT

Several authors have presented a strong argument in favor of devoting more resourses to postharvest research and development efforts in developing countries (Bourne, 1983; Mukai, 1987; Okezie, 1998). Although minimizing postharvest losses of already produced food is more sustainable than increasing production to compensate for these losses, less than 5% of the funding for agricultural research is allocated to postharvest research areas (Kader, 2003). In a more recent discussion paper, Goletti and Wolff (1999) stated that "while research on the improvement of agricultural production has received considerable attention and funding, until recently postharvest activities have not attracted much attention from international research organizations (CGIAR, FAO, ACIAR, IDRC, GTZ, CIRAD, NRI, USAID)." They identified the following five reasons to justify an increased commitment to postharvest research by the international agricultural system: 1) high internal rates of return, 2) international public good character, 3) effect on poverty, 4) effect on food security and health, and 5) effect on sustainable use of resources. Goletti and Wolff (1999) concluded that: "As the significant contribution of postharvest research to CGIAR goals such as poverty reduction, food security and sustainability becomes clear, and in the light of high rates of return, the very skewed allocation of funds to production versus postharvest topics cannot be justified. Since so far, relatively little has been invested in postharvest research, there is potential for large impacts as constraints and bottlenecks are removed. It would thus be desirable to re-examine current funding priorities and to allocated a larger proportion of resources to the postharvest area."

CONCLUSIONS

Minimizing postharvest losses of horticultural perishables is a very effective way of reducing the area needed for production and/or increasing food availability. Solving the postharvest food distribution problems in a given country will require cooperation and

effective communication among all the research, extension, and industry personnel involved. Postharvest horticulturists need to coordinate their efforts with those of production horticulturists, agricultural marketing economists, engineers, food technologists, and others who may be involved in various aspects of the production and marketing system. In most cases, solutions to existing problems in the postharvest handling system require use of available information and application of available technologies at the appropriate scale rather than conducting new research, or developing new technologies. Overcoming the socioeconomic constraints is essential to achieving the goal of reducing postharvest food losses.

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Tables

Table 1. Examples of estimated postharvest losses of fresh fruits and vegetables in developing countries.

Country	Commodities	Postharvest losses (%)	Reference
Egypt	All fruits	20	Blond, 1984
	All vegetables	30	
	Grape	28	
	Potato	18	
	Tomato	43	
Venezuela	Broccoli	49	Guerra et al, 1998
	Cauliflower	33	
	Celery	48	
	Leek	20	
	Lettuce	35	

Table 2. Estimated postharvest losses of fresh produce in developed and developing countries.

Locations	Developed Countries		Developing Countries	
	Range (%)	Mean (%)	Range (%)	Mean (%)
From production to retail sites	2-23	12	5-50	22
At retail, foodservice, And consumer sites	5-30	20	2-20	10
Cumulative total	7-53	32	7-70	32

INTEGRATED POST HARVEST MANAGEMENT ESSENTIAL FOR REDUCING POST HARVEST LOSSES OF HORTICULTURAL CROPS

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Concept of post harvest food loss reduction

- Nature provides enough food for every living being and it is up to us to sustain the bounties of Nature.
- In the good old days food was available in plenty but a phenomenal increase in population in modern times has resulted in food scarcity.
- Attention to the concept of post harvest food loss reduction as a significant means to increase food availability was drawn by the World Food Conference held in Rome in 1974.
- Food loss prevention became a priority area with the FAO and an Action Programme became operational focusing mainly on durable food grains.
- In May 1980, an Expert Consultation on Food Loss Prevention in Perishable Crops, mainly covering fruit and vegetables was held in Rome.

Importance post harvest management

- The target of National Horticulture Mission (NHM) is to double the production of fruits and vegetables from the existing level of production of 150 million tons to 300 million tons by the end of XI Plan.
- The production of fruits and vegetables will have significance only when they reach the consumer in good condition and at a reasonable price.
- At present there is a considerable gap between the gross production and net availability of fruits & vegetables due to heavy post harvest losses.
- Post harvest management, processing and value addition did not get due attention in most of the previous horticulture development programmes, as a result there was no significant effect on loss reduction.
- On the contrary quantity of losses has increased with the increase in production.
- It is a matter of great satisfaction that under NHM holistic growth of horticulture is linked with post harvest management, processing and marketing.

Present Scenario

- The production of fruit and vegetables during 2005-06 as per the data available with the National Horticulture Board (NHB) is 58.740 and 109.050 million tones respectively.
- Latest information indicates that 30% of all fruits produced, roughly worth Rs.13,600 crore and 30% of the vegetables crops the country produces worth Rs.14,100 crore are lost due to mismanagement.
- According to a joint study conducted earlier by CII and McKenzie, at least 50% of the production of fruits and vegetables in the country is lost due to wastage and value destruction.
- Taking the loss rate at 50% the net availability of fruits and vegetables should be about 84 million tonnes.
- As per the specifications of the National Institute of Nutrition at least 300g of fruit and vegetables are to be consumed by an individual for a balanced diet.
- Thus when the population is one billion, the minimum requirement of fruit and vegetables in the country is 110 million tonnes in order to meet our basic nutrition requirement.
- This figure does not include the requirements of the food processing industry or export. Considering the fact that there is a shortfall of about 26 million tonnes of fruit and vegetables.
- It is evident that the only way to cope with the present situation is to give a massive thrust to post harvest loss reduction in order to make available more food from the existing level of production.

Importance of Fruits and Vegetables in Diet

- Fruit and vegetables in general, except for a few, are not considered to be the primary source of carbohydrate, protein and fat.
- However, some of them with storage roots and tubers are rich in carbohydrate, particularly starch, in amounts comparable to the cereal crops, and can be used as staple food.
- The leguminous vegetables supply as much as 14 per cent protein, dry seeds supplying still more and the lipid content in most vegetables is less than 0.1 per cent.
- Most fruit, vegetables and root crops are rich in minerals, carotene (Pro-vitamin A) and vitamin C. Besides, there are some trace elements required by the body like copper, manganese and zinc, which act as enzyme cofactor. These are found in appreciable quantity in fruit and vegetables.
- The amount of nutrient can vary with the fruit or vegetables, cultural practices, stage of maturity, post-harvest handling and storage conditions.
- Once they are harvested, their composition goes on changing as a result of physiological and biochemical activities, which are natural processes.

Perishable nature of fruits and vegetables:

- Fruit and vegetables are living beings and they carry out transpiration, respiration, ripening and other biochemical activities, which adversely affect the quality.
- In addition, because of their high moisture content fruit and vegetables are inherently liable to deteriorate, especially under tropical conditions, and finally become unmarketable.
- Fruits and vegetables can be preserved in the fresh form by increasing their shelf life or can be processed into different products.
- The shelf life can be increased by storing them in a low temperature room or in controlled atmosphere storage in properly designed packages or wrapping etc.
- The consumption of preserved fruits and vegetables is still low all over the world compared to fresh ones but it is progressively increasing and will continue to do so in view of the seasonal availability of fresh commodities. In most of the developed countries consumption of processed products is relatively high. Processing industries are also beginning to emerge and grow in the less developed parts of the world.

Integrated Post Harvest Management (IPHM) – see (Fig-1)

- The production of fruits and vegetables will have significance only when they reach the consumer in good condition and at a reasonable price.
- At present there is a considerable gap between the gross production and net availability of fruits & vegetables due to heavy post harvest losses.
- The success of production lies in:
    1. Loss reduction,
    2. Prevention of market gluts,
    3. Proper distribution of the produce
    4. Subsequent use by adopting both traditional and modern post harvest technologies,
- 100% utilization of the production in one form or the other should be the motto.
- This can only be achieved by adopting Integrated Post Harvest Management (IPHM) system.

Immediate attention needed

- Harvesting of the produce at proper stage/maturity and applying ideal technique / method.
- Sorting should be accomplished in the farm. This will enable the farmer to have some access to nutrition;
- Packing stations should be established at nodal points to streamline the marketing of fresh horticultural produce.
- By primary processing, the inedible parts can be removed at the packing station before sending to city markets. This will help in reducing city garbage;

- Introduction of corrugated fibre board (CFB) there by paving the way for palletisation and mechanical loading and unloading to promote clean metros
- Establishment of pre-cooling facility by refrigeration/evaporative cooling in our supply chain;
- Improvement of the storage and packaging system by introducing low-cost on-farm techniques based on evaporative cooling to high-tech controlled and modified atmosphere (CA/MA) techniques;
- Encouraging minimally-processed fruits & vegetables as the demand for this is likely to increase;
- Introduction of rapid transportation and improvement in retail outlets. No useful purpose will be served by adopting improved post harvest technology methods unless a proper retail outlet is made since considerable deterioration takes place at the retailers end.
- Value addition by utilizing unmarketable / surplus horticultural produce and processing factory waste;
- Emphasis to processed products from indigenous fruits so that the growers get a remunerative price;
- Promoting bulk freezing, aseptic packaging and mobile processing facility during peak season to bring in price stability.
- Retailing is going through a transition phase in India. Lots of corporates have started making intervention in this area.
- Organized retail marketing of horticultural produce will definitely make a positive impact and improve the socio-economic conditions of small and marginal farmers of India.

Low Cost Appropriate Techniques of Preservation:

- Most of the commercial methods of preservation are expensive and beyond the means of the common people.
- Therefore, it is necessary to adopt low cost methods of preservation so that it can reach the grass root level. In this respect the following techniques are suggested:
    1. Zero energy cool chamber:
    2. Sun/Solar drying
    3. Home/cottage/small scale processing
    4. Lactic fermentation:
    5. Primary/semi/minimal Processing:

Utilization of fruit and vegetable Waste:

- A large amount of unmarketable as well as physically damaged fruit and vegetables that are without infection but would be spoiled on storage can be made into durable and value added products.
- In addition huge quantity of waste generated by fruit and vegetable processing factory could be utilized gainfully otherwise they would be converted into garbage creating environmental pollution.

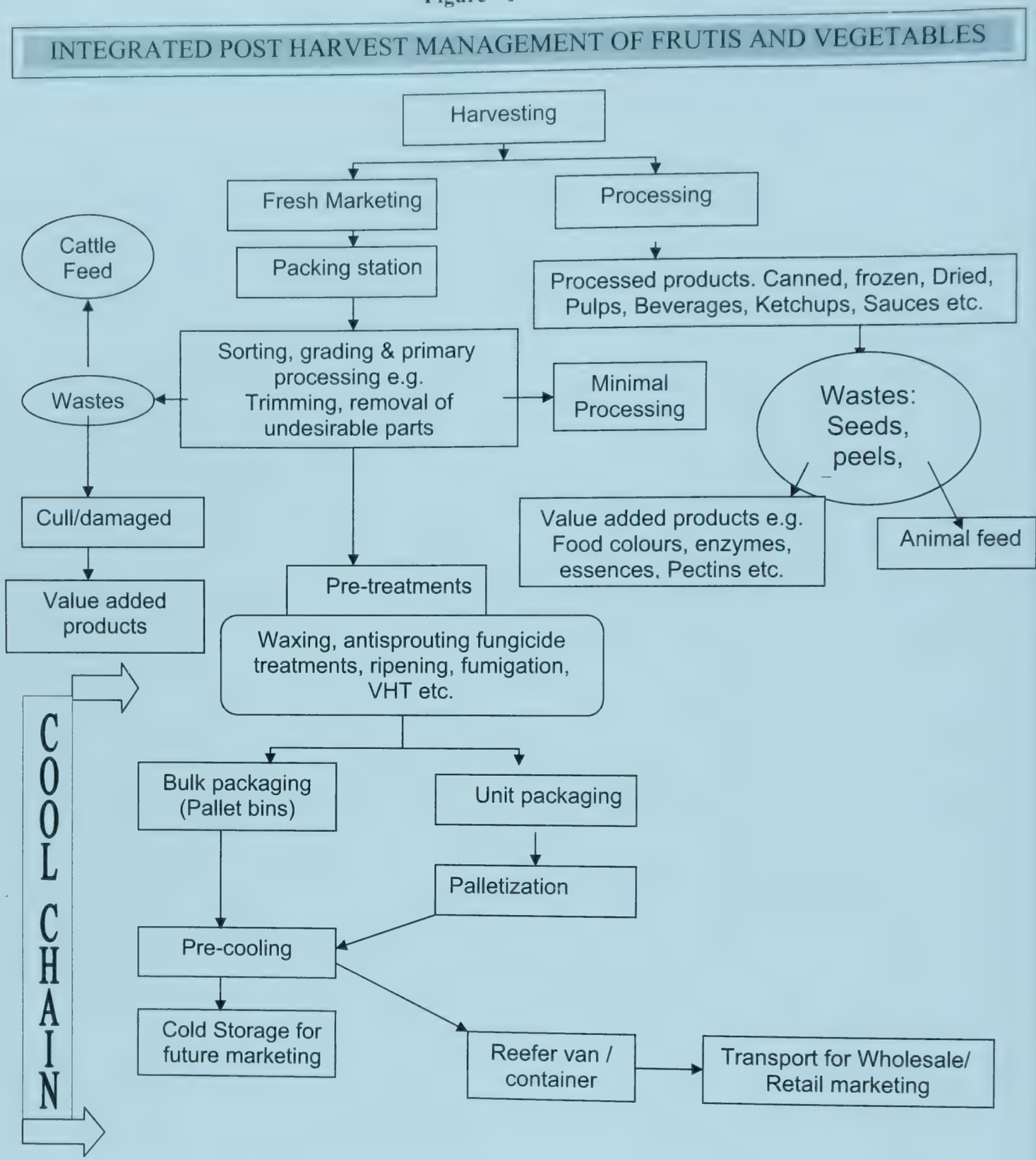
Price stability of horticultural produce

- Prices of seasonal fruits and vegetables fluctuate greatly and during the period of maximum availability the prices are unremunerative to the farmer.
- At other times, these commodities are so highly priced that the ordinary consumer finds it beyond his purchasing power.
- Another problem is that fruits and vegetables are not uniformly available throughout the country and some areas suffer from inadequate supply even when there is a glut in other parts.
- Integrated Post Harvest Management (IPHM) system would play a vital role in price stability of perishable horticultural produce.

Conclusion:

- It is very difficult to quantify the losses in different regions of the country; however, it may be stated that the losses depend on the post harvest infrastructure facility of the region.
- The losses are more in remote areas compared to places close to cities.
- Post harvest loss has to be gradually cut down by adopting appropriate storage and processing in order to achieve the target of meeting the food and nutritional requirements of the country.
- Every housewife in our country can save a substantial amount of horticultural produce, primarily fruits and vegetables, by adopting simple techniques of preservation.
- In addition to reducing wastage the village women/unemployed youth can be engaged in post harvest management/ processing activities for economic benefit.
- If adequate steps are not taken immediately then there is a danger of increasing the loss with the increase in production.
- Integrated Post Harvest Management (IPHM) will fulfill the objectives set by the National Horticulture Mission (NHM) for the XIth plan
    i. Post harvest loss reduction
    ii. Value addition
    iii. Export orientation
    iv. Quality improvement
    v. Strengthening agri-business.
- This will in turn achieve poverty alleviation, employment generation , environment protection and economic transformation of rural India.

Figure - 1


INTEGRATED POST HARVEST MANAGEMENT OF FRUTIS AND VEGETABLES
Harvesting
Fresh Marketing
Processing
Cattle Feed
Packing station
Processed products. Canned, frozen, Dried, Pulps, Beverages, Ketchups, Sauces etc.
Sorting, grading & primary processing e.g. Trimming, removal of undesirable parts
Wastes
Minimal Processing
Wastes: Seeds, peels,
Cull/damaged
Value added products e.g. Food colours, enzymes, essences, Pectins etc.
Animal feed
Value added products
Pre-treatments
Waxing, antisprouting fungicide treatments, ripening, fumigation, VHT etc.
COOL CHAIN
Bulk packaging (Pallet bins)
Unit packaging
Palletization
Pre-cooling
Cold Storage for future marketing
Reefer van / container
Transport for Wholesale/ Retail marketing

Methods for Determining Quality of Fresh Commodities

by Beth Mitcham, Marita Cantwell, and Adel Kader

VISUAL

The visual appearance of fresh fruits and vegetables is one of the first quality determinants made by the buyer whether the wholesaler, retailer or consumer. Often the appearance of the commodity is the most critical factor in the initial purchase (in addition to price) while subsequent purchases may be more related to texture and flavor.

Color

We perceive color when light reflected off the fruit or vegetable's surface falls upon the eye's retina; there is no color without light. Color perception depends on the type and intensity of light, chemical and physical characteristics of the commodity, and the person's ability to characterize color. Evaluating color can be subjective or objective:

Subjective: The human eye is used to evaluate color.

Advantages:

1. Faster and easier than objective measures.
2. Requires no specialized equipment.
3. Color charts or guides can be used as references for matching and describing colors as in bananas, nectarines and tomatoes.

Disadvantages:

1. Results can vary considerably due to human differences in color perception and human error.
2. Available light quantity and quality can influence color perception.

Objective: An instrument is used to provide a specific color value based on the amount of light reflected off the commodity surface or the light transmitted through the commodity.

Advantages:

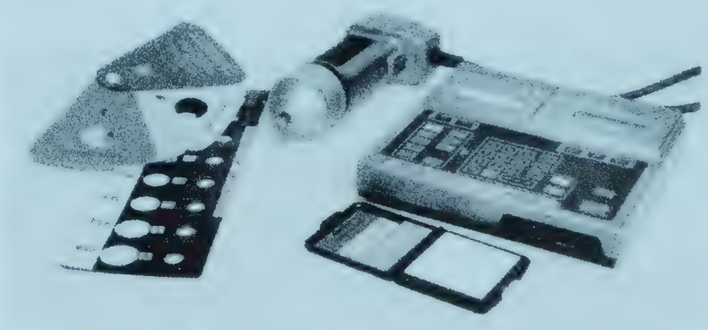
1. Less variability in color measurement.
2. Can measure small differences in color accurately.
3. Can be automated on the packingline.
4. Portable hand-held units are available (fig. 1).

Disadvantages:

1. Requires specialized equipment at a significant cost.
2. May be slower than subjective evaluation.

Subjective scoring of color may be more practical and faster and values can be referenced to objective color values and to pigment concentrations. For small leafy tissues, for example, samples representative of a 5 point color scale are evaluated for objective color values and chlorophyll and carotenoid concentrations. Routine evaluations are done by subjective scoring, but referencing to objective measurements adds valuable information to the scores.

Figure 1. *Determination of commodity color can be accomplished subjectively through the use of comparative color charts or objectively with a Minolta Colorimeter. Color charts can be very effective and useful if the colors truly match the color change in the commodity of interest. The Minolta Colorimeter can detect small differences in color and provides separate values for lightness to darkness, green to red and blue to yellow scales.*



Color Notation:

Hue: Red, yellow, green, blue, purple or intermediate colors between adjacent pairs of these basic colors, e.g. RY, YG, GB, BP.

Value of lightness: The degree to which an object is judged to reflect more or less light than another object.

Chroma or saturation: The degree of departure from the gray of the same lightness.

Gloss

Gloss is a visual aspect of quality that depends on the ability of a surface to reflect light. Products that are freshly harvested often have a bright, glossy surface and this appearance factor can be greatly reduced with weight loss and other postharvest handling conditions. There are small portable instruments from Minolta and BKY Gardner for measurement of gloss.

Shape & Size

Uniform and characteristic shape are important quality characteristics. Misshapen products may be more susceptible to mechanical injury and are generally avoided by consumers. Another example where shape is important is for broccoli. For the fresh market, compact broccoli florets are desirable while for fresh-cut, space between the florets is important to allow for cutting without injury. Size of product can also be important depending on its intended use. Consumers tend to associate large size with higher quality and view larger fruit as more mature.

A subjective evaluation of size and shape can be conducted on incoming product once the desirable and undesirable characteristics are determined. Size and shape charts are available for various commodities and weight is a fairly accurate measure of product size. The percentage of product which does not meet the desired characteristics can be recorded.

Absence of Defects

The product should be evaluated for the presence of defects. The level of tolerance for each type of defect such as cuts, bruises, disease, low-temperature injury, and physiological disorders should be determined. During quality evaluation, the percentage of fruit with each class of defect can be determined as a guide to overall product quality. A scoring system (such as 1 = none, 2 = slight, 3 = moderate, 4 = severe, and 5 = extreme) can be used to describe the incidence and severity of defects.

FIRMNESS

Firmness, or the degree of softness or crispness, is often measured using objective instruments. Subjective measure of firmness with the fingers can be useful for quick measures of gross differences in firmness, particularly of soft products.

Instruments

There are several firmness testers available including:

1. Magness-Taylor pressure tester - slide rule-type, spring-loaded penetrometer.
2. Effe-gi fruit penetrometer - hand-held probe with gauge for pounds-force.
3. Effe-gi penetrometer mounted on a drill-press stand.
4. UC Fruit Firmness Tester - Ametek penetrometer mounted on a drill-press stand.
5. Deformation Tester - determines deformation force for soft fruit.

Instruments #1 through 4 measure penetration force; instrument #5 measures deformation force and may be used for some fruits, such as tomatoes, papayas, and pears. Photos of some of these instruments can be seen in Figures 2 and 3.

The probes used in the instruments described above can also be mounted on computerized texture analyzers, which eliminate much operator variability. This allows not only determination of maximum force values, but also a texture profile. For example, a texture profile can show differences in the texture of chilled and nonchilled products.

Figure 2. *The most common way to measure firmness is resistance to compression or pounds-force (lbf.). There are three basic types of penetrometers available. The original Magness-Taylor has a slide-rule type device for measuring lbf. and is reliable, but bulky and heavy. The Effe-gi penetrometer is lightweight and easy to carry with an easy to read dial. Mounting the force guage on a drill-press stand, as seen in the UC Firmness Tester, increases the potential accuracy of results. Remove the peel before compression unless the peel is the tissue of interest for firmness measurement (usually is not).*

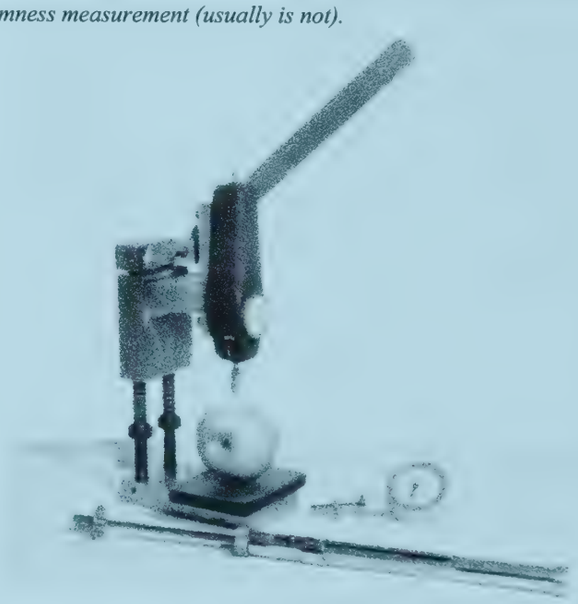


Figure 3. Texture Analysis system from Texture Technologies Corp.

Sample Size and Selection for Firmness

1. Select a random sample of product from several representative boxes including at least 15 to 25 fruits or vegetables or 3% of the sample.
2. Select product with a uniform size to avoid variation in firmness due to size (large fruit are usually softer than smaller fruit).
3. Make sure all fruit tested are comparable in temperature since warm fruit are usually softer than cold fruit.

Proper Use of Firmness Testers

1. Make 2 puncture tests per fruit (except very small fruit), once on each opposite cheek, midway between the stem and blossom end on sun and shade sides; avoid sunburned areas.
2. Remove a disc (larger than the tip to be used) of the skin with a vegetable peeler or sharp knife.
3. Use an appropriate tip (plunger), see Table 1, for each commodity.
4. All determinations for a given lot should be made by one person to minimize variability.
5. Hold the fruit against a stationary, hard surface and force the tip into the fruit at a uniform speed (take 2 seconds).
6. Depth of penetration should be consistently to the scribed line on the tip.
7. Record reading to the nearest 0.5 lb-force or 0.25 kg-force.

Table 1. Recommended tip sizes for firmness measurements.

Tip size	Commodities
11 mm (7/16-inch)	Apple
8-mm (5/16-inch)	Apricot, avocado, kiwifruit, mango, nectarine, papaya, peach
3-mm (1/8-inch)	Cherry, grape, strawberry
1.5-mm (1/16-inch)	Olive

Proper Units for Firmness

It is inappropriate to use the term "pressure" in association with firmness measurements using the devices described above. While pounds-force or kg-force are preferred in the industry, Newton (N) is the required unit for scientific writing. The conversion factors are as follows:

pound-force (lbf) x 4.448 = Newton (N)
kilogram-force (kgf) x 9.807 = Newton (N)

Maintenance of Firmness Testers

1. Before use each day, work the plunger in and out for 10 seconds to loosen up the springs inside the instrument.
2. Clean the tips after use to prevent clogging of the mechanism with juice.

Calibration of Firmness Testers

1. Hold the firmness tester in a vertical position and place the tip onto the pan of a scale.
2. Press down slowly on the firmness tester until the scale registers a given weight, then read the firmness tester. Repeat this comparison 3 to 5 times. If you find that the instrument is properly calibrated, it is ready to use.
3. If the instrument is not in agreement with the scale, find out the magnitude and direction of the differences and proceed as follows:

Magness-Taylor Pressure Tester:

- Remove the plunger assembly from the barrel of the instrument and remove the bolt and washers from the end of the plunger assembly.
- Pull the plunger and spring out of the metal cylinder, then shake the washers out of the cylinder.
- To make the instrument read lower, move washers from inside to outside the metal cylinder.
- To make the instrument read higher, move washers from outside to inside the metal cylinder.
- Reassemble and recheck for calibration.

Effe-gi Fruit Penetrometer:

- Unscrew the chrome guider nut to remove the plunger assembly.
- To make the instrument read lower, insert washers between the spring and the stationary brass guide.
- To make the instrument read higher, insert washers between the chrome guide nut and the stationary brass guide on the plunger shaft.
- Reassemble and recheck for calibration.
- If the indicator needle does not stop or does not release button hold, remove the plunger assembly, and then lubricate the inside of the instrument with an aerosol lubricant.

Firmness measurements may be useful for some fruit vegetables (melons, peppers) and even root vegetables (carrots, potato), but other measurements of texture are needed for stem and leafy tissues such as asparagus or celery (force for a blade to cut or shear). For lettuce, because of the variability of the structure of the leaves, it has been difficult to develop a standard assessment of crispness.

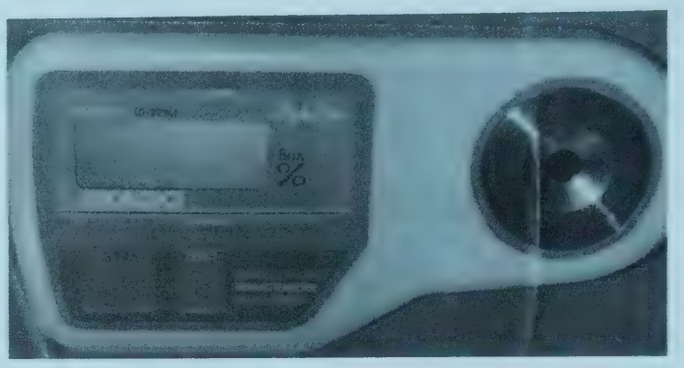
SOLUBLE SOLIDS CONTENT (SSC)

Sugars are the major soluble solid in fruit juice and therefore soluble solids can be used as an estimate of sugar content. Organic acids, amino acids, phenolic compounds, and soluble pectins also contribute to soluble solids. Soluble solids content (SSC) can be determined in a small sample of fruit juice using a refractometer (Figures 4 and 5). The refractometer measures the refractive index, which indicates how much a light beam will be slowed down when it passes through the fruit juice. The refractometer has a scale for refractive index and another for equivalent °Brix or SSC percent which can be read directly. Digital refractometers remove potential operator error in reading values.

For small products such as cherries, strawberries and grapes, the entire fruit can be juiced. For larger products, a sample wedge should be cut from stem to blossom end and to the center of the fruit to account for variability in SSC from top to bottom and inside to outside of the fruit. A garlic press works well for small samples. Cheesecloth may be necessary to remove pulp from the juice.

Figure 4. A wedge is cut from the commodity from stem to blossom end and to the center. The juice is extracted with a garlic press and a few drops are placed onto the glass of the refractometer. The refractometer is closed and held up to the light for viewing through the eyepiece. The internal scale will show the SSC of the juice.

Figure 5. Digital refractometer



The temperature of the juice is a critical factor for accuracy because all materials expand when heated and become less dense. For a sugar solution, the change is about 0.5% sugar for every 5.6°C (10°F). Good quality refractometers have a temperature compensation capability or at least a thermometer attached to them so that the operator can make the necessary corrections. It is essential to clean the refractometer between each reading and to standardize it with distilled water (should read a refractive index of 1.3330 at 20°C (68°F) or 0% SSC).

TITRATABLE ACIDITY

Titratable acidity (TA) can be determined by titrating a known volume of fruit juice with 0.1 N NaOH (sodium hydroxide) to an end point of pH = 8.2 as indicated by phenolphthalein indicator or by using a pH meter. (NaOH is added to the juice until the pH changes to 8.2. The milliliters of NaOH needed is used to calculate the TA) The TA,

expressed as percent malic, citric or tartaric acid, can be calculated as follows:

$$TA = \frac{\text{ml NaOH} \times \text{N(NaOH)} \times \textit{acid meq.factor} \times 100}{\text{ml juice titrated}}$$

Use the acid milliequivalent factor for the predominant organic acid in the commodity. The following table shows how to calculate TA for 3 organic acids.

Table 2. *Predominant organic acids to use for TA calculations of some commodities.*

Acid	Formula Wt	Equivalent Wt	*acid meq. factor*	Commodities
citric	192.12	64.0	*0.064*	berries citrus fruits pineapple
malic	134.09	67.05	*0.067*	apple, pear peach
tartaric	150.08	75.04	*0.075*	grape

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QUALITY ASSURANCE OF HARVESTED HORTICULTURAL PERISHABLES

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Keywords: inspection, quality assurance, quality control, standardization

Abstract

An effective quality assurance (QA) system throughout the handling steps between harvest and retail display is essential to provide a consistently good-quality supply of fresh horticultural crops to the consumers and to protect the reputation of a given marketing label. QA starts with the selection of the genotype and its proper time to harvest for the best appearance, textural, flavor (taste and aroma), and nutritional (including phytonutrients) quality. Careful harvesting and handling are required to minimize physical injuries. Each postharvest handling step has the potential to either maintain or reduce quality and in a few cases (such as ripening of climacteric fruits) improve eating quality. The availability of low-cost microcomputers and solid-state imaging systems have resulted in increased use of computer-aided video inspection to sort many products into two or more quality grades before marketing. Objective and nondestructive methods of differentiating horticultural perishables on the basis of their flavor and nutritional quality are being tested and will become excellent QA tools as they become more reliable and efficient. Safety assurance can be part of QA and its focus is on minimizing chemical and microbial contamination during production, harvesting, and postharvest handling of intact and fresh-cut fruits and vegetables. Future research and development efforts should focus on developing better methods of monitoring quality and safety attributes of fresh produce as part of a QA system.

1. Quality attributes

Quality of fresh produce includes appearance (size, shape, color, gloss, and freedom from defects and decay), texture (firmness, crispness, juiciness, mealiness, and toughness, depending on the commodity), flavor (sweetness, sourness (acidity), astringency, aroma, and off-flavors), and nutritive value (vitamins, minerals, dietary fiber, phytonutrients). The relative importance of each quality component depends on the commodity and the individual's interest (Kader, 1992). Most postharvest researchers, producers, and handlers are product-oriented in that quality is described by specific attributes of the product itself, such as sugar content, color, or firmness. In contrast, consumers, marketers, and economists are more likely to be consumer-oriented in that quality is described by consumer wants and needs (Shewfelt, 1999). Although consumers purchase fresh produce based on appearance and textural quality, their repeat purchases depend upon their satisfaction with flavor (taste and aroma). They are also interested in the health-promoting attributes and nutritional quality of fresh fruits and vegetables (Kader, 1988).

Several attempts have been made to develop portable instruments with sensors that detect volatile production by fruits as a way to detect maturity and quality. Other strategies include the removal of a very small amount of fruit tissue and measurement of total sugars or soluble solids content. Near-infrared detectors have great potential for nondestructive estimation of sugar content in fruits (Abbott, 1999). Until such methods become widely available, we will continue to depend on destructive techniques, such as soluble solids determination by a refractometer and titratable acidity measurement by titration, to evaluate flavor quality of fruits. Table 1 summarizes the proposed minimum 52 soluble solids content and maximum titratable acidity for acceptable flavor quality of fruits. These values will not guarantee the optimum flavor quality for each consumer but it

assures a minimum acceptability level for the majority of consumers. Additional research will likely result in a few changes in the values shown in Table 1. Use of these indices in a quality assurance program must be coupled with tolerances of deviation from the proposed averages because of the large variation among cultivars, production areas and seasons, maturity at harvest and ripeness stage at the time of evaluation.

2. Quality control and assurance

Quality control (QC) is the process of maintaining an acceptable quality level to the consumer. Quality assurance (QA) is the system whose purpose is to assure that the overall QC job is being done effectively (Hubbard, 1999). QA and QC are often used interchangeably to cover the planning, development, and implementation of inspection and testing techniques; they take time and a lot of training. A successful QA/QC system cannot be flexible, but it must be subject to constant review and improvement as conditions change (Hubbard, 1999).

Many attempts are currently being made to automate the separation of a given commodity into various grades and the elimination of defective units. The availability of low-cost microcomputers and solid-state imaging systems has made computer-aided video inspection on the packing line a practical reality. Solid-state video camera or light reflectance systems are used for detection of external defects, and x-ray or light transmittance systems are used for detecting internal defects (Abbott et al, 1997; NRAES, 1997). Further development of these and other systems to provide greater reliability and efficiency will be very helpful in quality control efforts.

An effective quality control and assurance system throughout the handling steps between harvest and retail display (Table 2) is required to provide a consistently goodquality supply of fresh horticultural crops to the consumers and to protect the reputation of a given marketing label. Quality control starts in the field with the selection of the proper time to harvest for maximum quality. Careful harvesting is essential to minimize physical injuries and maintain quality. Each subsequent step after harvest has the potential to either maintain or reduce quality; few postharvest procedures can improve the quality of individual units of the commodity (Cavalieri, 1999; Kader, 1988; Kader, 1992; Shewfelt *et al.*, 1993).

Exposure of a commodity to temperatures, relative humidities, and/or concentrations of oxygen, carbon dioxide, and ethylene outside its optimum ranges will accelerate loss of all quality attributes. The loss of flavor and nutritional quality of fresh intact or cut fruits and vegetables occurs at a faster rate than the loss of textural and appearance quality. Thus, QC/QA programs should be based on all quality attributes and not only on appearance factors as often is the case. More research is needed to identify the reasons for the faster loss of flavor than appearance quality and to develop new strategies for extending postharvest-life based on flavor to match that based on appearance.

3. Standardization and inspection of fresh produce

Grade standards identify the degrees of quality in a commodity that are the basis of its usability and value. Such standards, if enforced properly, are essential tools of quality assurance during marketing and provide a common language for trade among growers, handlers, processors, and receivers at terminal markets. Some production areas like California, USA enforce minimum standards concerning produce quality, maturity, container, marking, size and packing requirements. This provides orderly marketing and equity in the marketplace and protects consumers from inedible and poor quality produce. The California Department of Food and Agriculture is also responsible for enforcing provisions of laws governing the sale of foods labeled as organic.

The U.S. standards for fresh fruit and vegetable grades are voluntary, except when 53 required by industry marketing orders, by the buyer, or for export marketing. The USDA, Agricultural Marketing Service is responsible for developing, amending, and implementing grade standards (for more information access the following website: http://www.ams.usda.gov/standards). Inspection is done either on a continuous basis (where one or more inspectors are assigned to a packinghouse to make frequent quality checks of the commodity along the

packing lines), or on a sample basis (where representative samples of a prescribed number of boxes out of a given lot are randomly selected and inspected to determine whether the product meets the grade specification for which it is packed). When inspection is completed, certificates are issued by the inspector on the basis of applicable official standards.

To ensure uniformity of inspection: (1) inspectors are trained to apply the standards, (2) visual aids (color charts, models, diagrams, photographs and the like) are used whenever possible, (3) objective methods for determining quality and maturity are used whenever feasible and practical, and (4) good working environments with proper lighting are provided. Recently, the Fresh Products Branch of the USDA's Agricultural Marketing Service equipped inspectors with digital cameras and enhanced computer technology for taking and transmitting images of produce or containers. AMS is offering the images to applicants over the Internet as an additional resource in its fresh fruits and vegetables inspection service. Inspectors also use the imaging to confer with produce quality experts working in USDA's headquarters in Washington, D.C. The imaging provides a quick, visual confirmation of product appearance and defects, damage from shifted loads, brands and container markings, and container condition. It can facilitate "ecommerce" (buying and selling produce via the Internet) and help the produce industry quickly resolve disputes over the quality or condition of shipments.

International standards for fruits and vegetables were introduced by the Organization for Economic Cooperation and Development beginning in 1961, and now there are standards for about 40 commodities. Each includes three quality classes with appropriate tolerances: Extra class = superior quality (equivalent to "U.S. Fancy"); Class I = good quality (equivalent to "U.S. No. 1"); and Class II = marketable quality (equivalent to "U.S. No. 2"). Class I covers the bulk of produce entering into international trade. These standards or their equivalents are mandatory in the European Union countries for imported and exported fruits and vegetables.

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Useful Websites

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http://www.fao.org/inpho
http://www.usda.gov

Tables 1.

Proposed minimum soluble solids content (SSC) and maximum titratable acidity (TA) for acceptable flavor quality of fruits (Kader, 1999).

Fruit	Minimum SSC%	Maximum TA%
Apple	10.5-12.5 (depending on cultivar)	
Apricot	10	0.8
Blueberry	10	—
Cherry	14-16 (depending on cultivar)	
Grape	14-17.5 (depending on cultivar) or SSC/TA ratio of 20+	
Grapefruit	SSC/TA ratio of 6+	
Kiwifruit	14	—
Mandarin	SSC/TA ratio of 8+	
Mango	12-14 (depending on cultivar)	
Muskmelons	10	—
Nectarine	10	0.6
Orange	SSC/TA ratio of 8+	
Papaya	11.5	—
Peach	10	0.6
Pear	13	—
Persimmon	18	—
Pineapple	12	1.0
Plum	12	0.8
Pomegranate	17	1.4
Raspberry	8	0.8
Strawberry	7	0.8
Watermelon	10	—

Table 2. Quality assurance procedures during handling of horticultural perishables.

Handling Steps	Quality Assurance Procedures
Harvesting	Training workers on proper maturity and quality selection, careful handling, and protecting produce from sun exposure.
Packinghouse Operations	Checking product maturity, quality, and temperature upon arrival. Implementing an effective sanitation program to reduce microbial load. Checking packaging materials and shipping containers to ensure they meet specifications. Training workers on proper grading by quality (defects, color, size), packing, and other packinghouse operations. Inspecting a random sample of the packed product to ensure that it meets grade specification. Monitoring product temperature to assure completion of the cooling process. Maintaining effective communications with quality inspectors and receivers to correct any deficiencies as soon as they are identified.
Transportation	Inspecting all transport vehicles before loading for functionality and cleanliness. Training workers on proper loading and placement of temperature-recording devices in each load. Keeping records of all shipments as part of the "traceback" system.
Handling at Destination	Checking product quality upon receipt and moving it quickly to the appropriate storage area. Shipping product from distribution center to retail markets without delay and on a first in/first out basis unless its condition necessitates a different order.

Perspective
Flavor quality of fruits and vegetables

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Abstract: Fruits and vegetables are important sources of vitamins, minerals, dietary fiber, and antioxidants. The relative contribution of each commodity to human health and wellness depends upon its nutritive value and per capita consumption; the latter is greatly influenced by consumer preferences and degree of satisfaction from eating the fruit or vegetable. Flavor quality of fruits and vegetables is influenced by genetic, preharvest, harvesting, and postharvest factors. The longer the time between harvest and eating, the greater the losses of characteristic flavor (taste and aroma) and the development of off-flavors in most fruits and vegetables. Postharvest life based on flavor and nutritional quality is shorter than that based on appearance and textural quality. Thus, it is essential that good flavor quality be emphasized in the future by selecting the best-tasting genotypes to produce, by using an integrated crop management system and harvesting at the maturity or ripeness stage that will optimize eating quality at the time of consumption, and by using the postharvest handling procedures that will maintain optimal flavor and nutritional quality of fruits and vegetables between harvest and consumption.

Keywords: appearance life; aroma; consumer preferences; flavor life; odor; taste; texture

INTRODUCTION

Providing better-flavored fruits and vegetables at affordable prices is likely to increase their consumption, which would be good for producers and handlers (making more money or at least staying in business) as well as for consumers (increased consumption of healthy foods). Devoting more attention to flavor and nutritional quality of fruits and vegetables is strongly recommended. This should include identification of the reasons for postharvest life based on flavor being shorter than postharvest life based on appearance, selection of cultivars with flavor life that is close to appearance life, and modification of current postharvest handling recommendations on the basis of maximizing flavor life potential.[1]

New cultivars of fruits and vegetables with better flavor and nutritional quality are being and will likely continue to be developed using both biotechnology and plant breeding methods, especially for commodities for which easily monitored markers of good flavor and/or nutritional quality are identified. Developing innovative technologies for maintaining optimal temperature and relative humidity, for delaying losses of flavor and nutritional quality, and for assuring safety will require collaboration between public and private organizations.

Worldwide availability of both conventionally and organically grown fruits and vegetables and their value-added products continues to increase in terms of their number as well as their expanded season of availability with production in northern and southern hemisphere countries. Continued consolidation and vertical integration among producers and marketers will characterize the global marketing systems for fresh produce. This will facilitate collaboration among producers and marketers from various production areas to limit the marketing period on the basis of availability of superior flavor quality products from each production area.

COMPOSITION *VERSUS* FLAVOR

Fruit and vegetable flavor depends upon taste (balance between sweetness and sourness or acidity, and low or no astringency) and aroma (concentrations of odor-active volatile compounds). Although taste and aroma are well integrated in their contribution to the overall flavor, aroma is often considered to play a dominant role in flavor.[2–4] Thus, future research on flavor quality must include both non-volatile and volatile constituents that contribute to taste and aroma of fruits and vegetables.

Sweetness is determined by the concentrations of the predominant sugars, which are ranked relative to sucrose in the following order of sweetness: fructose (1.2) > sucrose (1.0) > glucose (0.64). Sourness or acidity is determined by the concentrations of the predominant organic acids, which are ranked relative to citric acid in the following order of sourness:

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citric (1.0) > malic (0.9) > tartaric (0.8); some amino acids, such as aspartic and glutamic, may also contribute to sourness. Minerals such as calcium, phosphorus, and potassium combine with the organic acids and influence the buffering capacity and the perception of acidity. Soluble sugars and organic acids contribute indirectly to phenolic metabolism by altering pH and through use as building blocks for phenolic compounds.[5] In fruits and beverages, tactile sensation of astringency is elicited primarily by flavanol polymers (proanthocyanidins or condensed tannins). Variations in proanthocyanidin composition, such as polymer size, extent of galloylation, and formation of derivatives, affect astringency;[6] individuals perceive astringency differently because of variations in salivary flow rates and in their preferences. Future research is needed to determine the extent of variation among individuals in perception of sweetness and sourness.

Soluble solids measured by a refractometer include sugars, organic acids, soluble pectins, anthocyanins and other phenolic compounds, and ascorbic acid. Thus the correlation between soluble solids and sweetness is low in some cases. Plant breeders can benefit from availability of quick methods for measuring total sugars and titratable acidity in fruits of their advanced breeding lines. Consumer acceptance of nectarine, peach, plum, and pluot cultivars is related to soluble solids concentration or the ratio of soluble solids to titratable acidity in ripe fruits.[7–9] Byrne[10] indicated that it is possible to combine high soluble solids with good fruit size in stone fruit cultivar development. Future research on correlating soluble solids to acidity ratio to sensory flavor should include alternatives, such as subtracting acidity from soluble solids.[11]

Volatile compounds are largely esters, alcohols, aldehydes, and ketones (low-molecular-weight compounds). Large numbers of volatile compounds have been identified in many fruits and vegetables, but more research is needed to identify which compounds contribute to the desirable aroma of each commodity, their threshold concentrations, potency, and interactions with other compounds. Metabolic pathways for volatiles biosynthesis, including those for amino acids, fatty acids, and carotenoids, are diverse and often highly integrated with other portions of both primary and secondary metabolism. More research is needed to identify the key substrates and enzymes involved to be able to target those that can increase desirable aroma compounds.

Voilley and Etievant[4] edited a book that provides an excellent overview of developments in flavor science and their implications for the food industry, including characterization of aroma compounds, flavor retention and release from the food matrix, and influences on flavor perception. Continued research is needed to match aroma sensory and instrumental data and to elucidate texture–aroma interactions and odor–taste interactions in flavor perception. Greger and Schieberle[12] concluded that odor-active components in a complex aroma profile can be elucidated using approaches of molecular sensory science, including aroma reconstitution experiments based on the results of quantitative data. They found that the responses of the human odorant receptors toward apricot aroma can be closely mimicked by a mixture of 18 volatiles of identical concentrations to those present in the apricot fruit. Similar studies should be conducted on other fruits and vegetables for which such information is not available. Odor threshold concentrations should be determined in the juice or purée of the commodity rather than in water.

Although work on non-destructive methods to measure quality using acoustical and near-infrared systems has led to commercial use (in a packing line situation) to select fruits with acceptable flavor quality, there is a need for continued development of non-destructive sensing of flavor quality. This should include sensing degree of freshness (time since harvest); use of near-infrared spectrophotometry to estimate concentrations of flavor-related, non-volatile constituents; use of aroma-sensing technology (electronic nose) to detect desirable and undesirable aroma volatiles;[13] and taste-sensing technology (electronic mouth or tongue).

GENETIC IMPROVEMENTS OF FLAVOR QUALITY

The relative importance of each of the flavor quality factors and their interactions depends upon the commodity. The greatest need is to produce new fruit genotypes with better flavor, which means high sugars and moderate to high acids (with balance between them), low phenolics, and enough of the desirable, odor-active volatiles for good aroma. Since flavor quality involves perception of the tastes and aromas of many compounds, it is much more challenging to manipulate than other quality factors. This has been true for plant breeders in the past and it will continue to be so with biotechnology approaches. This may be the reason that improvement of flavor quality has received much less attention from biotechnologists so far than textural quality of fruits.[14,15] Textural quality and related sensory attributes, such as juiciness, turgidity, and crispness, do influence human perception of flavor and future research should contribute to improved understanding of the physical and chemical changes that contribute to desirable texture and flavor of fruits and vegetables.

High priority should be given to replacing poor flavor cultivars with good flavor cultivars from among those that already exist and/or by selecting new cultivars with superior flavor and good textural quality. Flavor is a complex, multigenic trait providing unique challenges to breeders and has not been a high priority. Selection for yield, fruit size, and shelf-life characteristics in particular has had unintended negative consequences on fruit flavor.[3] Baldwin[2] concluded that the bottom line for flavor quality is still genetic. Breeders need more information and

analytical tools in order to select for flavor quality. Use of wild material may be necessary in breeding programs to regain flavor characteristics that have been lost from some commodities. Use of molecular markers that relate to flavor may help identify important enzymes in flavor pathways.[2]

Bood and Zabetakis[16] concluded that techniques using radiolabeled compounds and precursor studies are important tools in providing information regarding potential biosynthetic pathways leading to flavor formation. In the next steps, biochemical techniques have provided information on the enzymes involved in these pathways. Once these enzymes were characterized, molecular biological techniques have been used to clone these enzymes. These studies have provided valuable information on how the genes involved in the biosynthesis of flavor are expressed during ripening, and whether it is feasible to overexpress these genes in order to maximize flavor production.[12,16] Future research should continue to identify the biochemical pathways responsible for production of the odor-active component for each commodity and the key enzymes involved and their controlling genes. Such information can be used by geneticists in their programs to select genotypes with superior flavor.

Pech *et al.*[17] listed the following pathways and targeted genes that are candidates for improving sensory quality: increasing the sucrose content of fruit through down-regulating genes encoding sucrose-hydrolyzing enzymes; lipoxygenase, which catalyzes the hydroperoxidation of lipid precursors of some aroma compounds; and phytoene synthase, which is involved in the carotenoid pathway, from which some volatiles are synthesized. Down-regulation of ethylene synthesis or perception aimed at extending shelf-life of climacteric fruits often results in lower production of aroma compounds.[17–22] Defilippi *et al.*[19] found that the alcohol acyltransferase (AAT) enzyme is under ethylene regulation and seems to play a role in determining ester formation. In addition, the availability of fatty acids and amino acids (especially isoleucine) showed important changes associated with ester production under ethylene regulation. Future research is needed to better understand how to reduce ethylene production and/or action without reducing ester biosynthesis.

PREHARVEST FACTORS

The influences of genome, growing conditions, harvest maturity, and storage regime on compounds that serve as precursors for ester formation are critical factors that determine the ultimate levels of volatile esters in fresh and stored apples.[18,23] Climatic conditions (temperature, light, rain, wind) and cultural practices (planting density, tree pruning, fruit thinning, nutrient and water quantities; control of weeds, diseases, and insects) that result in high yield often result in less than optimal flavor quality. Future research is needed to identify optimal cultural practices that maximize flavor quality, such as optimizing crop load and avoiding excess nitrogen and water, which along with low calcium shorten the postharvest life of fruits due to increased susceptibility to physical damage, physiological disorders, and decay.[24] Selection of optimal integrated crop management systems for each commodity should be based not only on yield but also on quality attributes including flavor. Adoption by producers of cultural practices that will improve flavor quality but slightly reduce yield will be encouraged by the willingness of buyers to pay a higher price for the products to compensate the producer for the loss in yield.

MATURITY AND RIPENESS STAGE AT HARVEST

I rate maturity stage at harvest as the second most important factor (after genotype) influencing flavor quality of fruits and vegetables. Non-fruit vegetables are best tasting when harvested immature, while fruit vegetables and fruits are best tasting when harvested fully ripe. Synthesis of non-volatile and volatile compounds influencing fruit flavor increases with maturation and ripening. However, harvesting fruits before they reach optimal maturity is a common commercial practice because of the higher prices when the supply is low at the beginning of the harvest season of each kind and cultivar of fruits. Minimum maturity indices are often not enforced by the regulatory authorities. Another reason for harvesting climacteric fruits before their optimal maturity stage based on flavor is to assure sufficient firmness to withstand handling procedures and to maximize their storage potential. However, Fellman *et al.*[23] showed that when apples are harvested at the early pre-climacteric stage and kept in either air or controlled atmospheres for various durations before marketing, they never reach good eating quality. Future research and development efforts should be directed to encourage producers to harvest fruits at partially ripe to fully ripe stages by developing handling methods that protect the fruits from physical damage.

POSTHARVEST FACTORS

Much of the published information about optimal harvesting and handling procedures has largely been based on reducing quantitative losses by maintenance of appearance and textural quality of fruits and vegetables.[25–29] Forney[30] concluded that controlling changes in volatiles and flavor that occur during marketing and storage presents an additional challenge: since the goal is to optimize fruit flavor upon delivery to the consumer, it is not enough to harvest fruit with good flavor; this flavor must be maintained or enhanced during storage and marketing. This produces many challenges to understanding the environmental and physiological factors affecting volatile composition during postharvest handling throughout the distribution chain. As technology develops

to provide more precise control over the holding environment, including temperature, humidity, and atmosphere composition, these new capabilities can be used to optimize volatile composition and flavor.[30]

Kader *et al.*[31] reported that the longer the time between harvest and eating, the greater the losses of characteristic aroma and the development of off-flavors in tomatoes. My collaborators and I found similar trends in strawberries[32] and all the other fresh fruits that we have tested during the past 30 years. Thus, it is very important to identify optimal postharvest handling conditions (time, temperature, relative humidity, atmospheric composition) that maintain flavor quality of fruits and their value-added products. Postharvest life should be determined on the basis of flavor rather than appearance. The end of flavor life results from losses in sugars, acids, and aroma volatiles (especially esters) and/or development of off-flavors due to fermentative metabolism (accumulation of acetaldehyde, ethanol, and/or ethyl acetate to levels above their threshold concentrations that cause undesirable flavor) or transfer of undesirable odors, such as those caused by sulfurous compounds, from fungi or other sources. Off-flavors in foods can arise from environmental sources, such as air, water, and packaging materials, from chemical and biochemical reactions occurring within the food itself, and from flavor–matrix interactions, all of which can unbalance the intrinsic flavor profile.[33]

Baldwin *et al.*[34] concluded that the individual contributions of flavor compounds and their interactions in terms of the overall flavor quality of fresh produce need to be determined for many important horticultural crops. The effect of harvest maturity, handling, storage temperature and shelf-life duration needs to be evaluated for flavor quality shelf-life, which may be shorter than appearance shelf-life for many commodities.

More research is needed to determine both the positive and negative effects of using the ethylene action inhibitor, 1-methylcyclopropene, on flavor quality of fruits and vegetables that are currently treated or likely to be treated in the future to extend their postharvest life.[35–37]

VALUE-ADDED PRODUCTS

Research on how to maintain quality and safety of fresh-cut fruits and vegetables increased greatly during the past 15 years in response to commercial development of value-added, ready-to-eat products. Strategies for delaying browning and softening of wounded plant tissues and for maintaining their safety by minimizing microbial growth have been developed. However, more research is needed to enable extension of post-cutting life based on flavor and nutritional quality. Also, there is a need to develop new ready-to-eat, value-added products with good flavor and adequate shelf-life.

Beaulieu[38] hypothesized that recycling of esters during storage of certain fresh-cut fruits disturbs the delicate fine balance of characteristic volatiles. Consistently decreasing acetates along with increasing non-acetates could alter the overall perceived desirable flavor attributes during fresh-cut melon storage, even though volatile esters are still abundant. Fresh-cut 'Gala' apples displayed a slightly different trend whereby both acetates and non-acetate esters decreased appreciably during storage. Further research is needed to identify the underlying mechanism for loss of characteristic and desirable flavor in fresh-cut fruit and vegetable products and how to delay such losses.

PROCESSING FACTORS

In a recent review, Rickman *et al.*[39,40] concluded that the initial thermal treatment of processed products can cause loss of water-soluble and oxygen-labile nutrients such as vitamin C and the B vitamins. However, these nutrients are relatively stable during subsequent canned storage owing to the lack of oxygen. Frozen products lose fewer nutrients initially because of the short heating time in blanching, but they lose more nutrients during storage owing to oxidation. Phenolic compounds are also water-soluble and oxygen-labile, but changes during processing, storage, and cooking appear to be highly variable by commodity. These processed forms offer added convenience to the consumer and offer diversity to the diet, while generally sacrificing little in terms of nutrition.[39,40] It is very likely that changes in nutritional composition are accompanied by changes in flavor quality of fruits and vegetables.

Although processing methods, especially thermal processing, can alter textural and flavor quality, they are very useful in terms of year-round availability and convenience. Future research and development efforts should focus on selecting cultivars with better flavor and nutritional quality, optimizing maturity/ripeness stage in relation to flavor quality at the time of processing, and on identifying the processing methods that would retain good flavor and nutritional quality of the processed fruit and vegetable products.

CONCLUSIONS

Providing better-tasting fruits and vegetables to consumers, especially in convenient forms and at affordable cost, is likely to increase consumption of these healthy foods. To achieve this goal, future research and development efforts should address the following objectives:

1. Replacing poor-flavor cultivars with good-flavor cultivars from among those that already exist and/or selecting new cultivars with desirable flavor and textural quality.

2. Identifying optimal cultural practices that maximize flavor quality, such as optimizing crop load and avoiding excess nitrogen and water.
3. Encouraging producers to harvest fruits at partially ripe to fully ripe stages by developing handling methods that protect the fruits from physical damage and methods for non-destructive determination of maturity and quality indices.
4. Identifying optimal postharvest handling conditions (time, temperature, relative humidity, atmospheric composition) that maintain flavor quality of fruits and vegetables and their value-added products. Postharvest life should be determined on the basis of flavor rather than appearance.
5. Developing ready-to-eat, value-added products with good flavor and adequate shelf-life.
6. Optimizing maturity/ripeness stage in relation to flavor quality at the time of processing and selecting processing methods to retain good flavor of the processed products.

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The Return on Investment in Postharvest Technology for Assuring Quality and Safety of Horticultural Crops

Adel A. Kader [1]

Summary

Reduction of postharvest losses can increase food availability to the growing world population, decrease the area needed for production, and conserve natural resources. Strategies for loss prevention include use of genotypes that have longer postharvest-life; use of integrated crop management systems and Good Agricultural Practices (GAP) that result in good keeping quality of the commodity; and use of proper postharvest handling practices in order to maintain quality and safety of the products. There are many postharvest technologies that extend the marketable life of fruits and vegetables. However, some of these technologies do not have a positive return on investment (ROI) due to the large capital investments needed for their implementation and/or the increasing competition related to globalization of produce marketing. Appropriate postharvest technologies when used effectively can greatly enhance profitability, but no single technology is a substitute for the many integrated steps involved in proper postharvest management. A few examples of the ROI in various postharvest technologies are presented. Similar site-specific and commodity-specific studies are needed as basis for selecting the most suitable postharvest handling technologies in each situation

Keywords: Horticultural crops; Postharvest technology; Quality and safety; Return on investment.

1. Introduction

1.1. Quality factors:

Quality, the degree of excellence or superiority, is a combination of attributes, properties, or characteristics that give each commodity value in terms of its intended use. The relative importance of each quality component depends upon the commodity or the product and how it is utilized and varies among producers, handlers, and consumers. To producers a given commodity must have high yield and good appearance, must be easy to harvest, and must withstand long-distance shipping to markets. Appearance quality, firmness, and shelf life are important from the point of view of wholesale and retail marketers. Consumers judge quality of fresh fruits, ornamentals, and vegetables on the basis of appearance (including freshness) at the time of initial purchase. Subsequent purchases depend upon the consumer's satisfaction in terms of flavor (eating) quality of the edible products (Kader, 2002 and Kader & Rolle, 2004).

Grade standards identify the degrees of quality in a commodity that are the basis of its usability and value. Such standards, if enforced properly, are essential tools of quality assurance during marketing and provide a common language for trade among growers, handlers, processors, and receivers at terminal markets. Some production areas enforce minimum standards concerning produce quality, maturity, container, marking, size and packing requirements. This provides orderly marketing and equity in the market-place and protects consumers from inedible and poor quality produce (Kader, 2002).

1.2. Safety factors:

Safety factors in fruits and vegetables include naturally-occurring toxicants, such as glycoalkalosids in potatoes; natural contaminants, such as fungal toxins (mycotoxins) and bacterial toxins and heavy metals (cadmium, lead, mercury); environmental pollutants; residues of pesticides; and microbial contamination. While health authorities and scientists regard microbial contamination as the number one safety concern, many consumers rank pesticide residues as the most important safety issue (Kader & Rolle, 2004).

Unless fertilized with animal and/or human waste or irrigated with water containing such waste, raw fruits and vegetables normally should be free of most human and animal enteric pathogens. Organic fertilizers, such as chicken manure, should be sterilized before use in fruits and vegetables to avoid the risk of contaminating fresh produce with Salmonella, Listeria and other pathogens. Commodities that touch the soil are more likely to be contaminated than those that do not come in contact with the soil. Strict adherence to Good Agricultural Practices (GAP) during production, Good Hygienic Practices (GHP) during postharvest handling and Good Manufacturing Practices (GMP) during processing are strongly recommended to minimize microbial contamination (Kader & Rolle, 2004). These practices have a positive ROI since lack of safety can have major negative consequences in terms of marketability.

1.3. Postharvest losses of horticultural perishables:

Both quantitative and qualitative losses occur in horticultural commodities between harvest and consumption (Shewfelt & Prussia, 1993; Kader, 2002 and Gross *et al.*, 2004). Qualitative losses, such as loss in edibility, nutritional quality, caloric value, and consumer acceptability of the products, are much more difficult to assess than quantitative losses. Standards of quality and consumer preferences and purchasing power vary greatly among countries and across cultures and these differences influence marketability and the magnitude of postharvest losses (Kader & Rolle, 2004).

Postharvest losses vary greatly among commodities and production areas and seasons. In developed countries, the losses of fresh fruits and vegetables are estimated to range from 2% for potatoes to 23% for strawberries, with an overall average of 12% losses between production and consumption sites. In contrast, the range of produce losses in devel-

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oping countries is estimated to vary from 5 to 50%, with an overall average of 22%. Losses at the retail, food-service, and consumer levels are estimated at approximately 20% in developed countries and about 10% in developing countries. Overall, about one third of horticultural crops produced are never consumed by humans (Kader, 2003 & 2005).

Reduction of postharvest losses can increase food availability to the growing world population, decrease the area needed for production and conserve natural resources. Strategies for loss prevention include: (1) use of genotypes that have longer postharvest-life; (2) use of integrated crop management systems and GAP that result in good keeping quality of the commodity; and (3) use of proper postharvest handling practices in order to maintain quality and safety of the products (Kitinoja & Kader, 2002 and Kader, 2005).

There are many postharvest technologies that extend the marketable life of fruits and vegetables. However, many of these technologies are inappropriate economically due to the large capital investments needed for their implementation and the increasing competition related to globalization of produce marketing. Appropriate postharvest technologies when used effectively can greatly enhance profitability, but one must keep in mind that no single technology is a substitute for the many integrated steps involved in proper postharvest management (Gorny & Kitinoja, 1999 and Kitinoja & Gorny, 1999). In this report, I will present a few examples of the ROI in various postharvest technologies. Similar site-specific and commodity-specific studies are needed as basis for selecting the most suitable postharvest handling technologies.

2. Postharvest Management Procedures that are Critical to Maintaining Quality and Safety of Horticultural Crops

2.1 Preparing fruits and vegetables for market:

Preparation of produce for market may be done in the field or in a packinghouse where the product is cleaned and sanitized, sorted by quality and size, waxed and treated with an approved fungicide for some commodities, then packed in shipping containers (Shewfelt & Prussia, 1993 and Kader, 2002). Packing protects the product against mechanical injuries and contamination during marketing. Corrugated fiberboard containers are the most commonly used for produce packing, but these are being replaced with reusable plastic containers, in some cases, at the request of some produce buyers. Packaging materials (such as trays, cups, wraps, liners and pads) may be used to help immobilize the produce. Mechanical packing systems based on the volume-fill or tight-fill method are more commonly used than hand packing procedures. Packing and packaging methods can influence airflow rate around the commodity, which is an important factor in management of temperature and relative humidity (Kader & Rolle, 2004). There are no published studies of the ROI in the various preparations for market procedures. However, many of these procedures are essential for successful marketing of horticultural perishables.

2.2 Temperature and relative humidity management:

Temperature is the most important environmental factor that influences the deterioration of harvested commodities. Most temperate, perishable horticultural commodities last longest at temperatures near 0°C. At temperatures above the optimum, the rate of deterioration increases 2- to 3-fold for every 10°C rise in the temperature (Table 1). Temperature influences how other internal and external factors influence the commodity and has a dramatic effect on the spore germination and growth of pathogens. Temperatures outside the optimal range can cause rapid deterioration due to the freezing, chilling (of subtropical and tropical commodities), or heat disorders.

Table 1. Effect of temperature on deterioration rate of a non-chilling sensitive commodity (Kader, 2002)

Temperature (°C)	Assumed Q_{10}*	Relative velocity of deterioration	Relative postharvest-life	Loss per day (%)
0	---	1.0	100	1
10	3.0	3.0	33	3
20	2.5	7.5	13	8
30	20	15.0	7	14
40	1.5	22.5	4	25

$$^{*}Q_{10} = \frac{\text{Rate of deterioration at temperature T+10°C}}{\text{Rate of deterioration at T}}$$

Relative humidity (RH) can influence water loss, decay development, incidence of some physiological disorders, and uniformity of fruit ripening. Condensation of moisture on the commodity (sweating) over long periods of time is probably more important in enhancing decay than is the RH of ambient air. An appropriate RH range for storage of fruits is 85 to 95% while that for most vegetables varies from 90 to 98%. The optimal RH range for dry onions and pumpkins is 70 to 75%. Some root vegetables, such as carrot, parsnip and radish can best be held at 95 to 100% RH (Kader, 2002; Gross *et al.*, 2004 and Kader & Rolle, 2004).

RH can be controlled by one or more of the following procedures: (1) adding moisture (water mist or spray, steam) to air by humidifiers; (2) regulating air movement and ventilation in relation to the produce load in the cold storage room; (3) maintaining temperature of the refrigeration coils within about 1°C of the air temperature; (4) providing moisture barriers that insulate walls of storage rooms and transit vehicles; (5) adding polyethylene liners in containers and using perforated polymeric films for packaging; (6) wetting floors in storage rooms; (7) adding crushed ice in shipping containers or in retail displays for commodities that are not injured by the practice and (8) sprinkling produce with sanitized-clean water during retail marketing of commodities that benefit from misting, such as leafy vegetables, cool-season root vegetables and imma-

ture fruit vegetables (such as snap beans, peas, sweet corn and summer squash).

2.3 Cooling methods:

Temperature management, which is the most effective tool for extending the shelf life of fresh horticultural commodities, begins with the rapid removal of field heat by using one of the cooling methods listed in Table (2).

Table 2. Comparison among cooling methods (Thompson *et al.*, 1998)

Variable	Cooling method				
	Ice	Hydro	Vacuum	Forced-air	Room
Cooling times (h)	0.1-0.3	0.1-1.0	0.3-2.0	1.0-10.0	20-100
Water contact with the product	yes	yes	no	no	no
Product moisture loss (%)	0-0.5	0-0.5	2.0-4.0	0.1-2.0	0.1-2.0
Capital cost	high	high	medium	low	low
Energy efficiency	low	low	high	low	low

Packing a product with crushed or flaked ice can quickly cool it and can provide a source of cooling and high RH during subsequent handling. However, its use is limited to a few products that tolerate direct contact with ice and are packaged in moisture-resistant containers. Clean-sanitized water is used as the cooling medium in hydrocooling (shower or immersion systems) of some commodities that tolerate water contact and are packaged in moisture-resistant containers. Vacuum cooling is used for a few leafy vegetables that release water vapor quickly allowing them to be cooled rapidly. Water loss of about 1% causes 6°C product cooling. In forced-air cooling, refrigerated air is used as the cooling medium and is forced through produce packed in boxes or pallet bins. Most horticultural perishables can be cooled by forced-air cooling (Thompson *et al.*, 1998).

2.4. Refrigerated transport and storage:

Cold storage facilities should be appropriately designed and adequately equipped. They should be of good construction and be properly insulated. Their insulation should include a complete vapor barrier on the warm side of the insulation; strong floors; adequate and well-positioned doors for loading and unloading; effective distribution of refrigerated air; sensitive and properly located controls; refrigerated coil surfaces designed to adequately minimize the difference between the coil and air temperatures and adequate capacity for expected needs. Commodities should be stacked in the cold room with air spaces between pallets and room walls so as to ensure proper air circulation. Storage rooms should not be loaded beyond their limit for proper cooling. In monitoring temperatures, commodity temperature rather than air temperature should be measured.

Temperature management is critical during long distance transport. Loads must be stacked to enable proper air circulation to facilitate removal of heat from the produce as well as incoming heat from the atmosphere and off the road. Also, produce must be stacked in ways that minimize mechanical damage, braced and secured. Transit vehicles must be cooled before loading the commodity. Delays between cooling after harvest and loading into transit vehicles should be avoided. Proper temperature maintenance should be ensured throughout the handling system (Kader & Rolle, 2004).

There are continued improvements in attaining and maintaining the optimum environmental conditions (temperature; relative humidity; concentrations of oxygen, carbon dioxide and ethylene) in transport vehicles. Treating fruits with ethylene to initiate their ripening during transportation is feasible and is used commercially to a limited extent on mature-green bananas and tomatoes. Products are commonly cooled before loading and are loaded with an air space between the palletized product and the walls of the transport vehicles to improve temperature maintenance. In some cases, vehicle- and product- temperature data are transmitted by satellite to a control center allowing all shipments to be continuously monitored. Air-ride suspensions, in new truck models can also eliminate damage caused by vibration during transportation. Controlled-atmosphere and precision temperature management allow non-chemical insect control for markets which possess quarantine restrictions against pests endemic to exporting countries and for markets that do not want their produce exposed to chemical fumigants.

Mixing several produce items in one load is common and often compromises have to be made in selecting optimal temperatures and atmospheric composition when transporting chilling-sensitive with non-chilling sensitive commodities or ethylene-producing with ethylene-sensitive commodities. In the latter case, ethylene scrubbers can be used to remove ethylene from the circulating air within the vehicle. Several types of insulating pallet covers are available for protecting chilling-sensitive commodities when transported with non-chilling-sensitive commodities at temperatures below the threshold chilling temperature.

2.5 Return on investment in maintaining the cold chain:

Mitchell *et al* (1996) showed that a one-hour delay in cooling strawberries after harvest resulted in a 10% loss due to decay during marketing. The resulting economic loss was greater than the increased cost of expedited handling of the strawberries by more frequent deliveries of harvested fruits to the cooling facility and initiation of forced-air cooling.

Jordan *et al* (1987) showed that the average net revenue for lettuce kept below 5°C was $9.75 per carton, compared to $9.06 per carton for lettuce held at 5°C or higher. This loss of $0.69 per carton due to quality deterioration caused by poor temperature management resulted in a loss of $172.50 per truckload of 900 cartons.

2.6 Return on investment in reducing water loss:

Thompson *et al* (1998) found that table grapes handled near ideal conditions of prompt cooling after harvest and

maintenance of proper temperature (0-2°C) and RH (90-95%) throughout handling from shipping point to the retail market lost about 2% of their weight at harvest. In contrast, grapes that were subjected to delays between harvest and cooling and were handled at temperatures above the optimal range (higher than 5°C) and relative humilities below 90% lost about 7% of their weight at harvest. The stems of these grapes turned brown, which reduced their quality. The combination of the additional 5% weight loss and lower appearance quality resulted in a 15% loss in value of the grapes and returns to the shipper and marketer. This economic loss is greater than the cost of improved management of temperature and RH by using perforated plastic liners in the boxes and by minimizing delays before cooling with humidified and forced air.

3. Postharvest Treatments Designed to Minimize Produce Contamination and Maximize Quality

3.1 Treatments to reduce microbial contamination:

Over the past few years, food safety has become and continues to be the number one concern of the fresh produce industry. The U.S. Food and Drug Administration published in October 1998 a Guide to Minimize Microbial food Safety Hazards for Fresh Fruits and Vegetables . This guide is based on the following principles: (1) Prevention of microbial contamination of fresh produce is favored over reliance on corrective actions once contamination has occurred; (2) In order to minimize microbial food safety hazards in fresh produce, growers, packers or shippers should use GAP and GMP in those areas over which they have control; (3) Fresh produce can become microbiologically contaminated at any point along the farm-to-table food chain. The major source of microbial contamination with fresh produce is associated with human or animal feces; (4) Whenever water comes in contact with produce; its quality dictates the potential for contamination. The potential of microbial contamination from water used with fresh fruits and vegetables must be minimized; (5) The use of animal manure or municipal biosolid wastes as fertilizers should be closely managed in order to minimize the potential for microbial contamination of fresh produce and (6) Worker hygiene and sanitation practices during production, harvest, sorting, packing and transport play a critical role in minimizing the potential for microbial contamination of fresh produce.

Clean-disinfected water is required in order to minimize the potential transmission of pathogens from water to produce, from healthy to infected produce within a single lot, and from one lot to another over time. Waterborne microorganism, including postharvest plant pathogens and agents of human illness, can be rapidly acquired and taken up on plant surfaces. Natural plant surface contours, natural openings, harvest and trimming wounds and scuffing can be points of entry as well as provide safe harbor for microbes. In these protected sites, microbes are largely unaffected by common or permitted doses of postharvest water sanitizing treatments (Table 3).

Maintaining the Cold Chain for Perishables

Harvest	¥ Protect the product from the sun
	¥ Transport quickly to the packinghouse
Cooling	¥ Minimize delays before cooling
	¥ Cool the product thoroughly as soon as possible
Temporary Storage	¥ Store the product at optimum temperature
	¥ Practice first in first out rotation
	¥ Ship to market as soon as possible
Transport to Market	¥ Use refrigerated loading area
	¥ Cool truck before loading
	¥ Load pallets towards the center of the truck
	¥ Put insulating plastic strips inside door of reefer if truck makes multiple stops
	¥ Avoid delays during transport
	¥ Monitor product temperature during transport
Handling at Destination	¥ Use a refrigerated unloading area
	¥ Measure product temperature
	¥ Move product quickly to the proper storage area
	¥ Transport to retail markets or foodservice operations in refrigerated trucks
Handling at home or food service oulet	¥ Display at proper temperature range
	¥ Store product at proper temperature
	¥ Use the product as soon as possible

It is essential, therefore, that an adequate concentration of sanitizer is maintained in water in order to kill microbes before they attach or become internalized in produce. This is important in some preharvest water uses (such as spraying pesticides or growth regulators) and in all postharvest

Table 3. Water sanitizing chemicals used in produce handling (Kader & Rolle, 2004)

Sanitizing chemicals	Advantages	Disadvantages
Chlorine compounds, Calcium hypochlorite, Sodium hypochlorite, Chlorine gas or Chlorine dioxide	Low cost	Corrosive, irritating, trihalomethanes are by-product
Iodine compounds	Low cost, non irritating	Slightly, corrosive, staining
Ozone	Faster action on microorganisms, fewer disinfection by-products than chlorine	Higher cost than chlorine
Peroxy-acetic acid or Hydrogen peroxide	More effective in removing and controlling microbial biofilms	Higher cost than chlorine

procedures involving water, including washing, cooling, water-mediated transport (flumes) and postharvest drenching with calcium chloride or other chemicals.

3.2 Treatments to minimize water loss:

Transpiration, or evaporation of water from the plant tissues, is one of the major causes of deterioration in fresh horticultural crops after harvest. Water loss through transpiration not only results in direct quantitative losses (loss of saleable weight), but also causes losses in appearance (wilting and shriveling), textural quality (softening, flaccidity, limpness and loss of crispness and juiciness), and nutritional quality. Transpiration (water loss) is a physical process that can be controlled by various postharvest treatments which are applied to the commodity (surface coatings and other moisture barriers) or which involve manipulation of the environment (maintenance of high relative humidity).

Treatments that can be applied to the commodity to minimize water loss include the following:

a. Curing of certain root vegetables, such as garlic, onion, potato and sweet potato.
b. Waxing and other surface coatings used on some used on some commodities, such as apple, citrus fruits, nectarine, peach, plum, pomegranate and tomato.
c. Packaging in polymeric films that act as moisture barriers.
d. Careful handling to avoid physical injuries, which increase water loss from produce.
e. Addition of water to those commodities that tolerate misting with water, such as leafy vegetables.

3.3 Treatments to reduce ethylene damage:

The promotion of senescence in harvested horticultural crops by ethylene (0.1ppm or higher) results in acceleration of deterioration and reduced postharvest life. Ethylene accelerates chlorophyll degradation and induces yellowing of green tissues, thus reducing quality of leafy-, floral-, and immature fruit-vegetables and foliage ornamentals. Ethylene induces abscission of leaves and flowers, softening of fruits and several physiological disorders. Ethylene may increase decay development of some fruits by accelerating their senescence and softening and by inhibiting the formation of antifungal compounds in the host tissue.

The incidence and severity of ethylene induced deterioration symptoms depend upon temperature, exposure time, and ethylene concentration. For example, yellowing of cucumbers can result from exposure to 1 ppm ethylene for 2 days or to 5 ppm ethylene for 1/2 day at 10°C. Also, the effects of ethylene are cumulative throughout the postharvest life of the commodity (Kader, 2002).

Treating ornamental crops with 1-methylcyclopropene (1-MCP), which is an ethylene action inhibitor, provides protection against ethylene damage and is used commercially. In July 2002, 1-MCP at concentrations up to 1 ppm was approved by the US Environmental Protection Agency for use on apples, apricots, avocados, kiwifruit, mangoes, nectarines, papayas, peaches, pears, persimmons, plums, and tomatoes. The first commercial application was on apples to retard their softening and extend their postharvest-life. As more research is completed, the use of 1-MCP will no doubt be extended to several other fruits and vegetables.

3.4 Treatments for decay control:

A major cause of losses in perishable crops is the action of a range of microorganisms on the commodity. Fungi and bacteria may infect the plant organ at any time. In fruits, latent infections, in which the fungus invades the fruit tissue shortly after flowering, become apparent only when the fruit starts to ripen. Postharvest rots frequently occur as a result of rough handling during the marketing process and are caused by a wide array of microorganisms. The grey mold *Botrytis cineria* is a very important cause of loss in many commodities (such as grapes, kiwifruit, pomegranates, raspberries and strawberries) and is an aggressive pathogen, even at low temperatures. Virus infection frequently lowers the quality of perishable commodities, usually as a result of visual deterioration, although viruses may also affect flavor and composition.

Curing is a postharvest treatment that facilitates certain anatomical and physiological changes that can prolong the storage life of some root crops. It is one of the most effective and simple means of reducing water loss and decay during subsequent storage of root, tuber and bulb crops.

Sanitation practices include treatment to reduce populations of microorganisms on equipment, on the commodity, and in the wash water used to clean it. Water washes alone are effective in removing nutrients that allow microorganisms to grow on the surfaces of produce as well as in removing inoculum of postharvest pathogens. Sanitizers that reduce inoculum levels of decay organism from fruit surfaces include treatments added to water dumps and spray or dip washes. These treatments inactivate spores brought into solution from fruit or soil and prevent the secondary spread of inoculum in water. Sanitizing washes may consist of halogenated compounds (e.g., hypochlorous acid from chlorine gas or sodium hypochlorite and chlorine dioxide) or ozonated water.

Treatments for decay control include: (1) heat treatments, such as dipping mangoes for 5 minutes in 50°C water to reduce subsequent development of anthracnose; (2) use of postharvest fungicides, such as imazalil and/or thiabendazole on citrus fruits; (3) use of biological control agents, such as Bio-Save (*Pseudomonas syringae*) and Aspire (*Candida oleophila*) alone or in combination with fungicides at lower concentrations on citrus fruits; (4) use of growth regulators such as gibberellic acid or 2, 4-D to delay senescence of citrus fruits; (5) use of 15-20% CO_2 in air or 5% O_2 on strawberries, cane berries, figs and pomegranates; and (6) use of SO_2 fumigation (100 ppm for one hour) on grapes.

3.5 Treatments for insect control:

A large number of insects can be carried by fresh fruits, vegetables and flowers during postharvest handling. Many of these insect species, especially the fruit flies of the family Tephritidae (e.g. Mediterranean fruit fly, Oriental fruit

fly, Mexican fruit fly and Caribbean fruit fly) can seriously disrupt trade among countries. Continuing globalization of marketing fresh produce will be facilitated by use of acceptable disinfestation treatments, including ionizing radiation. Selection of the best treatment for each commodity will depend upon the comparative cost and the efficacy of that treatment against the insects of concern with the least potential for damaging the host (produce).

Currently approved quarantine treatments include certification of insect-free areas, use of chemicals (e.g. methyl bromide, phosphine and hydrogen cyanide), irradiation, cold treatments, heat treatments and some combinations of these treatments. The potential for additional treatments, such as new fumigants (carboryl sulfide, methyl iodide, and sulfuryl fluoride), insecticidal atmospheres (below 0.5% oxygen and/or 40-60% carbon dioxide) alone or in combination with heat treatments and ultraviolet radiation, is being investigated. Each of these treatments is usable on a limited number of commodities because of phototoxic effects on others.

4. Postharvest Treatments Designed to Manipulate the Environment around Produce in order to Enhance Quality

4.1. Modified atmosphere storage:

When used as supplements to keeping fresh horticultural perishables within their optimum ranges of temperature and relative humidity, controlled atmospheres (CA) or modified atmospheres (MA) can serve to extend their postharvest-life (Table 4). Optimum concentrations of oxygen and carbon dioxide lower respiration and ethylene production rates, reduce ethylene action, delay ripening and senescence, retard growth of decay-causing pathogens, and control insects. On the other hand, CA conditions unfavorable to a given commodity can induce physiological disorders and enhance susceptibility to decay.

CA transport is used to continue the CA chain for some commodities (such as apples, pears and kiwi fruits) that had been stored in CA since harvest. CA transport of bananas permits their harvest at a more fully-mature stage (higher yield). CA transport of avocados facilitates use of a lower temperature (5°C) than if shipped in air because CA ameliorates chilling injury symptoms. CA combined with precision temperature management allow non-chemical insect control in some commodities for markets that have restrictions against pests endemic to exporting countries and for markets that prefer organic produce.

Table 4. Classification of horticultural crops according to their controlled atmosphere storage potential at optimum temperatures and relative humidities (Kader, 2002)

Range of storage duration (months)	Commodities
More than 12	Almond, Brazil nut, cashew, filbert, macadamia, pecan, pistachio, walnut, dried fruits and vegetables
6-12	Some cultivars of apples and European pears
3-6	Cabbage, Chinese cabbage, kiwifruit, persimmon, pomegranate, some cultivars of Asian pears
1-3	Avocado, banana, cherry, grape (no SO_2), mango, olive, onion (sweet cultivars), some cultivars of nectarine, peach and plum, tomato (mature-green)
<1	Asparagus, broccoli, cane berries, fig, lettuce, muskmelons, papaya, pineapple, strawberry, sweet corn, fresh-cut fruits and vegetables, some cut flowers

The use of polymeric films for packaging produce and their application in modified atmosphere packaging (MAP) systems at the pallet, shipping container (plastic liner), and consumer package levels continues to increase MAP (usually to maintain 2 to 5% O_2 and 8 to 12% CO_2) is widely used in extending the shelf-life of fresh-cut vegetable and fruit products. Use of absorbers of ethylene, carbon dioxide, oxygen and/or water vapor as part of MAP is increasing. Although much research has been done on use of surface coatings to modify the internal atmosphere within the commodity, commercial applications are still very limited due to the inherent biological variability of the commodity.

At the commercial level, CA is most widely applied during the storage and transport of apples and pears. It is also applied to a lesser extent on kiwifruits, avocados, persimmons, pomegranates, nuts and dried fruits. Atmospheric modification during long-distance transport is used on apples, avocados, bananas, blueberries, cherries, figs, kiwifruits, mangoes, nectarines, peaches, pears, plums, raspberries and strawberries. Continued technological developments in the future to provide CA during transport and storage at reasonable cost (positive benefit/cost ratio) are essential to expanding its application on fresh fruits and vegetables.

4.2. Return on investment in using modified and controlled atmospheres:

Although MA/CA have been shown to be effective in extending postharvest life of many commodities (Table 4), commercial applications have been limited due to their relatively high cost. However, there are a few cases where a positive ROI (cost/benefit ratio) can be demonstrated. In a comparison of losses due to decay during retail marketing of strawberries shipped in air and those shipped in 15% CO_2-enriched air (modified atmosphere within pallet cover), MacLeod (1999) observed that use of the modified atmosphere reduced losses by 50% (average of 20% losses in air vs 10% losses in MA). The economic loss of 10% value ($50-75 per pallet) was much greater than the cost of using MA ($15-25 per pallet).

Use of modified atmosphere (MA) during marine transportation can extend the postharvest-life of many fruits and vegetables with short postharvest-life potential and allow use of marine transportation instead of air transport. Savings realized with the use of marine transportation are much greater than is the added cost of MA service (Dohring, 1999).

4.3. Ethylene exclusion and removal:

Many green vegetables and most floral products are

quite sensitive to ethylene damage. Ethylene must be kept away from these products. Ethylene contamination from ripening rooms can be minimized by 1) using ethylene levels of 100 ppm instead of the higher levels often used in commercial ripening operations, 2) venting ripening rooms to the outside after the exposure period is complete, 3) at least once per day ventilating the area around the ripening rooms or installing an ethylene scrubber, 4) use of battery-powered forklifts instead of engine driven units.

Ethylene-producing commodities should not be mixed with ethylene-sensitive commodities during storage and transport. Potassium permanganate, an effective oxidizer of ethylene, is used commercially as a scrubber. Scrubbing units based on the catalytic oxidation of ethylene are used to a limited extent in some commercial storage facilities.

Thompson *et al* (1989) estimated the capital costs of heated catalyst, catalytic converter, potassium permanganate scrubber and ventilation to be $11,800, 5,000, 1600, and 1000 respectively; annual operating costs were estimated to be $3'226, 979, 974, and 295, respectively. Thus, ventilation to keep ethylene concentration low in the storage room is the least expensive method followed by potassium permanganate-based ethylene scrubber.

4.4. Return on investment in reducing ethylene damage:

Ayoub *et al* (1987) evaluated the use of ethylene absorbers in extending shelf-life and Concluded that ethylene-absorbing blankets containing alumina coated with potassium permanganate should be used in all fruit and vegetable storage areas in order to ensure maximum shelf-life at an affordable cost. In a comparison of two mixed loads of fruits and vegetables in two marine containers with or without scrubbers shipped from California to South Korea, the total produce lost in the container without ethylene scrubbing was 2'645 lbs (out of 16'070 lbs) valued at $928, which is much higher than the $160 cost of the ethylene scrubbers (Ayoub *et al.*, 1987).

Jordan *et al* (1987) determined the economic effect of transportation management techniques to separate ethylene-generating commodities from ethylene-sensitive commodities to increase shelf-life. They estimated a shelf-life (time to loss of 50% of arrival quality) of 6.4, 5.6 and 5.1 days for lettuce exposed to low (<1ppm), medium (3-7ppm), and high (10-15ppm) ethylene concentrations, respectively. The net revenues of lettuce exposed to the low, medium, and high ethylene levels were $12'886, 10'164 and 8'165, respectively.

Thompson *et al* (1989) showed that adding an ethylene scrubber in storage facilities used for lettuce significantly reduced russet spotting, which is caused by exposure to ethylene (Morris *et al.*, 1978). The difference in value of lettuce that was protected from ethylene vs that which was exposed to ethylene was estimated to be 20 to 25%, which was greater than the cost of the ethylene scrubber. Similar results were found with kiwifruits, which soften very rapidly when exposed to as low as 50 ppb ethylene. Wills *et al* (2000) concluded that ethylene levels of 0.1ppm or higher result in 10-30% loss of potential Postharvest life of fruits and vegetables during marketing.

4.5. Treatments to enhance more uniform ripening of fruits:

Ethylene treatment is used commercially to enhance ripening rate and uniformity of some fruits, such as bananas, avocados, mangoes, pears, tomatoes, and kiwifruits. Optimal ripening conditions are as follows:

- Temperature: 18 to 25°C
- Relative humidity: 90 to 95 percent
- Ethylene concentration: 10 to 100 ppm
- Duration of treatment: 24 to 74 hours depending on fruit kind and maturity stage
- Air circulation: Sufficient to ensure distribution of ethylene within the ripening room
- Ventilation: Require adequate air exchanges to prevent accumulation of O_2 which reduces the effectiveness of C_2H_4

The potential for greater sales as a result of increased consumer satisfaction is likely to have higher value than the cost of fruit ripening. However, specific studies are needed to determine the ROI of fruit ripening procedures.

Concluding Remarks

The basic recommendations for maintaining postharvest quality and safety of produce are the same regardless of the distribution system (direct marketing, local marketing, export marketing). However, the type of appropriate technology needed to provide the recommended conditions depends upon the distance and time between production and consumption sites and intended use, such as fresh vs processing (Kader & Rolle, 2004):

The technology used elsewhere is not necessarily the best for use under conditions of a given developing country. Many of the recent modifications in postharvest technology in developed countries have been in response to the need to economize in labor, materials and energy use and to protect the environment. It is useful to study the currently used practices in other countries, but to select only those which are appropriate for local conditions based on their ROI. Expensive equipment and facilities without proper management are useless. People who operate such facilities are more important than their level of sophistication. Effective training and supervision of personnel must be an integral part of quality and safety assurance programs. Assuring food safety throughout the postharvest handling system is very critical to successful marketing of produce and should be given the highest priority. Much more research is needed to evaluate the ROI of all relevant postharvest technologies.

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Capital $ Investment in Postharvest Technology & Recovery of Invested Capital

by James R. Gorny, Davis Fresh Technologies and Lisa Kitinoja, Extension Systems International

In today's competitive global agricultural market it takes more than knowing how to effectively produce crops to succeed in business. Marketing fruits and vegetables at acceptable profit margins may involve timing the market either early or late in the season, to receive higher prices. Many producers undertake the strategy of trying to be the first grower/shipper to market product when prices are high and customer demand is strong. To execute this strategy special cultivars of fruits and vegetables have been developed by plant breeders and seed companies to mature very early in the season and allow grower/shippers to capitalize using this marketing stategy. Marketing produce late in the season or during the off-season is achieved by utilizing appropriate postharvest handling technologies. These technologies if used properly not only extend the marketable shelf life of fresh fruits and vegetables but allow grower/shippers marketing opportunities such as:

1. shipping product to distant markets,
2. storing product until higher market prices are offered due to diminished supplies,
3. providing customers with consistent supply of product.

A good example of how market prices and available supplies vary inversely is shown below. This example demonstrates how Chilean asparagus prices in the U.S. market vary inversely with supply and how a marketing window exists late in the season.

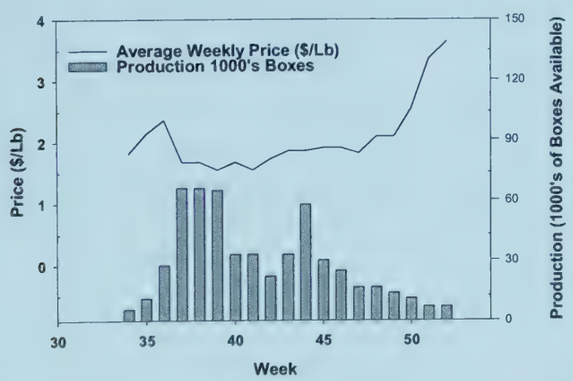

Figure 1. *Chilean asparagus prices and production availability.*

What Postharvest Technology Is Appropriate for Me ?

There are NO technological substitutes for sound postharvest management of temperature and relative humidity. However, postharvest technologies such as controlled atmosphere cold storage, are commercially available and are used effectively to reduce storage losses and extend the marketable life of many fruits and vegetables. But how appropriate is a given technology for your operations ? Implementing the use of a specific postharvest technology or handling practice may require a substantial investment of capital and knowing how much monetary value the use of a specific technology will add to your operation is an important question.

To determine if a specific postharvest technology is appropriate, cost effective and how long it will take to pay for potential increased operating and capital expenses, the following queries need to be answered:

Market Window

- Is there a market window which will potentially allow your crop, if stored, to bring a higher market price?
- Are other production areas or competing products coming to market during this potential marketing window?
- How long do I need to store my crop, to sell it during this marketing window?
- What is the expected price difference between when product is put into storage and when it will be marketed?

Postharvest Technologies

- What postharvest technologies are available to effectively store product for the length of time needed to sell during the targeted marketing window?

- What amount (percent) of product will be lost during storage using this new technology compared to selling nearly 100% marketable product immediately after harvest?

- What are the capital and operating costs associated with this technology?

Recovery Of Invested Capital (ROIC) Feasibility Studies

Once you have answered the above queries you are ready to evaluate whether or not a given postharvest technology is appropriate for your operations. The following is an example of the types of analyses you can perform to make this determination. Numerous variables will determine if a technology is economically feasible but this example will focus on the effects of:

1. crop value (on a per pound basis),
2. crop price deferential before and after storage and
3. losses incurred during storage.

The assumptions for this example are as follows. We wish to determine if the use of a portable controlled atmosphere storage chamber inside an existing cold storage is cost effective. We will assume the equipment can deliver the appropriate atmospheres and temperatures to allow us to hit our target marketing window. Remember that this is only an exercise and not a recommendation for any specific postharvest technology such as CA storage. Monetary figures are only for the sake of comparisons.

Assumptions

- 20 Pallet Spot Storage Capacity for CA Chamber (20,000 Lbs)
- $50,000 Capital Costs to Purchase
- ~ $10,000 per year total operating and finance costs:
  - $5,000 Operating Costs per year
  - $5,000 (10%) Annual Interest Rate on $50,000 Borrowed Money
- 10% Losses During Storage

Commodity Value Affects ROIC

In this example we will look at the effects of storing: 1) a low-value crop ($0.10/Lb), 2) a moderate-value crop ($1.00/Lb), and 3) a high-value crop ($10/Lb). We also want to determine what effects an increase in sales price after storage of 20%, 50%, 100% and 400% will have on ROIC.

Table 1. demonstrates that for a low-value commodity it is impossible to recover the invested capital for this technology even if prices rise by four fold (400%), after storage. In this case the net increase in profit by marketing later, is more than offset by storage losses, as well as operating and financing expenses, so that the technology will never pay for its implementation.

Table 1. *ROIC for a low-value commodity.*

Wt IN (Lbs)	Wt OUT (Lbs)	Sale Price ($/Lb)	Gross Value	Value Change	Net After Expenses	ROIC (Yrs)
20,000	20,000	0.10	2,000	0	0	0
20,000	18,000	0.10	1,800	(200)	(10,200)	∞
20,000	18,000	0.12	2,160	160	(9,840)	∞
20,000	18,000	0.15	2,700	700	(9,300)	∞
20,000	18,000	0.20	3,600	1,600	(8,400)	∞
20,000	18,000	0.40	7,200	5,200	(4,800)	∞

Examples of low-value commodities: lettuce, carrots, onions. ∞ = infinity

Table 2. demonstrates that for a moderate-value crop a price increase of nearly two fold (100%) is needed for the technology to pay for itself in 6.5 years. It also illustrates that if prices rise four fold (400%) the ROIC is reduced to 1.5 years. The ROIC of 1.5 years or seasons may actually be less if the technology can be used for other commodities. Another way of looking at this is, the more a technology can be used in one year, capital costs are spread over more pounds of product and this drives down per pound costs as well as the time to recover invested capital.

Table 3. demonstrates that ROIC when using a postharvest technology can be very fast for high-value commodities. For high-value commodities, the net percentage increase in price before and after storage does not need to rise drastically to fully recover invested capital in a short period of time. A 50% increase in prices before and after storage in this example has an ROIC of about 1 year or 1 turn of product.

Table 2. *ROIC for a moderate-value commodity.*

Wt IN (Lbs)	Wt OUT (Lbs)	Sale Price ($/Lb)	Gross Value	Value Change	Net After Expenses	ROIC (Yrs)
20,000	20,000	1	20,000	0	0	0
20,000	18,000	1	18,000	(2000)	(12,000)	∞
20,000	18,000	1.2	21,600	1,600	(8,400)	∞
20,000	18,000	1.5	27,000	7,000	(3,000)	∞
20,000	18,000	2	36,000	16,000	6,000	6.5
20,000	18,000	4	72,000	52,000	42,000	1.5

Examples of moderate-value commodities: asparagus, blueberry, strawberry.

Table 3. *ROIC for a high-value commodity.*

Wt IN (Lbs)	Wt OUT (Lbs)	Sale Price ($/Lb)	Gross Value	Value Change	Net After Expenses	ROIC (Yrs)
20,000	20,000	10	200,000	0	0	0
20,000	18,000	10	180,000	(20,000)	(30,000)	∞
20,000	18,000	12	216,000	16,000	6000	6.5
20,000	18,000	15	270,000	70,000	60,000	1
20,000	18,000	20	360,000	160,000	150,000	<1
20,000	18,000	40	720,000	520,000	510,000	<1

Examples of high-value commodities: golden raspberries, specialty herbs.

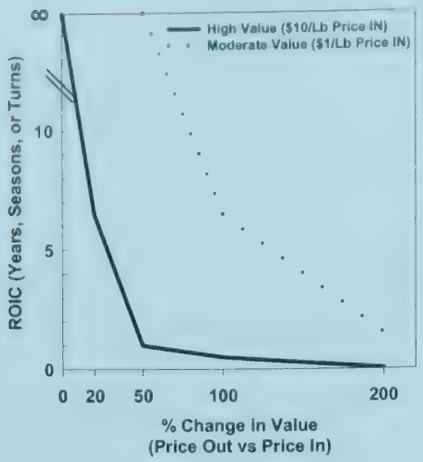

Figure 2. Commodity base value and price after storage both affect ROI

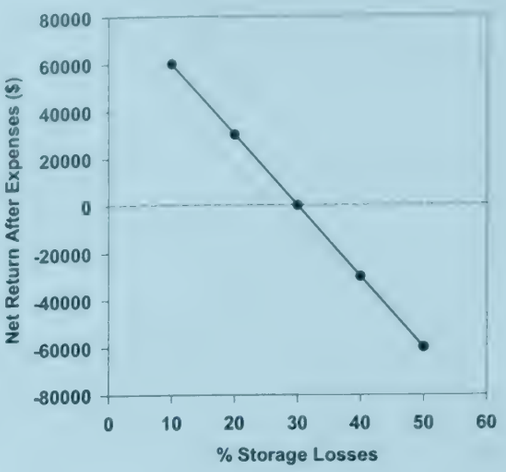

Figure 3. Storage losses affect ROIC

As shown in Figure 2, ROIC is affected by price changes before and after storage, as well as commodity value. Low-value commodities are not shown since they can almost never recover invested capital unless prices after storage skyrocket or if the technology is used on more than one time period per year. Use of new technology has the greatest potential for ROIC when used on high-value crops but also the greatest risk, if assumptions about storage losses or marketing conditions are incorrect

Storage Losses Affect ROIC

In the previous example we have a assumed a constant postharvest loss during storage of 10%. The example in Table 4 demonstrates the effects of increasing postharvest losses on net returns and ROIC. In this example the post storage sales price has been held constant at 50% above the initial crop storage price. Percent losses during storage are the variable and as losses increase there is less salable crop after storage and this reduces profitability and delays ROIC. When storage losses are greater than 30%, the operation begins to actually lose money and it would have been better to have marketed the crop immediately after harvest. Figure 3 is a graphical demonstration of the effects of losses during storage versus ROIC from data presented in Table 4. It is important to have realistic expectations of post storage losses that will be incurred.

Conclusion

There are many postharvest technologies which extend the marketable life of fruits and vegetable. However, many are inappropriate economically due to the large capital investments needed to implement these technologies as well as market forces. Use of appropriate postharvest technology when used effectively can greatly enhance profitability but one must keep in mind that any single technology is never a substitute for the many integrated steps involved in proper postharvest management.

Table 4. Losses During Storage Effects on ROIC.

Wt IN (Lbs)	% Losses	Wt OUT (Lbs)	Sale Price ($/Lb)	Gross Value	Value Change	Net After Expenses	ROIC (Yrs)
20,000	0	20,000	10	200,000	0	0	0
20,000	10	18,000	15	270,000	70,000	60,000	1
20,000	20	16,000	15	240,000	40,000	30,000	2
20,000	30	14,000	15	210,000	10,000	0	∞
20,000	40	12,000	15	180,000	(20,000)	(30,000)	∞
20,000	50	10,000	15	150,000	(50,000)	(60,000)	∞

COLD CHAIN MANAGEMENT

About 30% of the fruits and vegetables grown in India (40 million tons amounting to US$ 13 billion) get wasted annually due to gaps in the cold chain such as poor infrastructure, insufficient cold storage capacity, unavailability of cold storages in close proximity to farms, poor transportation infrastructure, etc. This results in instability in prices, farmers not getting remunerative prices, rural impoverishment resulting in farmers' frustrations and suicides.

India wastes more fruits and vegetables than it consumes. Despite having achieved national food security, the well-being of over 200 million Indian farmers and farm workers who have been the backbone of Indian agriculture continues to be a matter of grave concern. Operating costs for Indian cold storage units are over $60 per cubic meter per year compared to less than $30 in the West. Energy expenses make up about 28% of the total expenses for Indian cold storages compared to 10% in the West. These factors make setting up cold storages difficult, unviable and uneconomical. About 30-35% of the losses can be reduced by transporting the freshly harvested fruits and vegetables in refrigerated containers thus closing this gap in the cold chain.

Cold chain is a logistic system that provides a series of facilities for maintaining ideal storage conditions for perishables from the point of origin to the point of consumption in the food supply chain. The chain needs to start at the farm level (e.g. harvest methods, pre-cooling) and cover up to the consumer level or at least to the retail level. A well organized cold chain reduces spoilage, retains the quality of the harvested products and guarantees a cost efficient delivery to the consumer given adequate attention for customer service.

Failing to keep product at the correct temperatures can result in a variety of negative attributes including, among others, textural degradation, discoloring, bruising and microbial growth. Thus proving hazardous to consumer's health, leading to need for an integrated cold chain management.

The main feature of the chain is that if any of the links is missing or is weak, the whole system fails. The Cold chain logistics infrastructure generally consists of:

- Cold Storages
- Refrigerated Carriers
- Warehouse and Information Management systems

The cold chain industry has been seeing a lot of developments in terms of technology and size. Today the estimated size of the Indian cold-chain industry is Rs. 8,000-10,000 crores (US$ 1.80 - US$ 2.27 billion) which is expected to grow at 20 to 25% annually by 2015. Overall logistics and supply chain management is approximately a Rs. 60,000 crores (US$ 13.64 billion) and is expected growth over 10% during the next five years. Industry is

largely fragmented and unorganized; the Share of the organized sector is under 25%.

Major Trends & Developments in the industry includes s*erving India's Fresh Produce to international market, g*rowing realization of potential of India as a supplier of fresh produce, evolving from traders to Grower/Shippers and large investments in the cold chain management. Imports of fresh produce have been a driver of reform.

Although technology adoption is still at preliminary stage concept of Touting First expired First Out (FEFO) management is adopted by the cold chain industry. Achieving it has remained elusive. The difficulty is in knowing which pallets/cartons actually contain the produce that should be moved out first.

It is common knowledge that shipping out produce with the shortest remaining shelf life is the best way to reduce waste and increase profitability. But implementing an effective First Expired First Out (FEFO) program is not as easy as it seems. Perishables trading managers understand that real time, quality monitoring during transit and storage is a key component to success. But it is only the first step.

An efficient cold chain management program must be able to immediately alert when storage and transit environments are less than optimal. It must also be able to promptly analyze data and issue reports detailing the residual shelf life of produce in each individual pallet to facilitate further logistics decisions.

All this would make cold chain management a success in Indian scenario. Moreover, a quality product leads to a satisfied customer, greater demand, and overall protection of public health.

Fundamentals of Warehouse Operations

John J. Broaddus

Warehousing may be one of the world's oldest professions, but despite all the innovations in the world, including just-in-time production, the supply chain that connects manufacturers with consumers will never, ever, eliminate the need for warehouses. This is especially true of the food industry, where seasons, climate, and growing cycles can neither be conquered nor synchronized with holidays and consumer demand. And since the products handled in a food warehouse are perishable and often fragile, they demand extraordinary levels of care, custody, and control.

The food warehouse is a complex organization, one which relies on workers trained in food science, maintenance, computers, finance, safety, sanitation, material handling, and many other disciplines. But everyone connected with the operation of a refrigerated warehouse should be at least superficially familiar with the basic elements of warehouse operations. This chapter of the book provides an outline covering many of the basic operations of a refrigerated warehouse. It should be viewed not as a comprehensive statement, but, rather, as a brief overview. It will be expanded and refined in future editions. Also, keep in mind that no two warehouses are exactly alike. Specific operations depend on the construction of the warehouse, the products handled, the needs of the customer, the sophistication of the equipment, and the size and capabilities of the workforce.

Although every warehouse is different, the guiding principal in all public refrigerated warehouses is the same: to handle the customer's product as though it were your own.

1. Receiving Incoming Product

Receiving is one of the most important aspects of warehousing. The public warehouseman's responsibility for the care of incoming products generally begins when the delivering vehicle arrives on warehouse property, although some steps need to be taken even before the product arrives.

a. Office staff notifies dock of truck arrival. Generally, the warehouse will have a notice posted as to where the driver reports. Some facilities will photograph driver for security purposes.
b. Office sends appropriate papers (receipt tally and storage assignments if applicable) to dock supervisor for assignment.
c. Office compares shipper's and receiving documents for accuracy. A separate sheet can be used to record incoming product and then compare with what is on the bill of lading.
d. Office resolves any discrepancies and notifies customer as required.
e. If applicable, office enters storage location into database.
f. Check the seal on trailer and compare to number on bill of lading.
g. Ensure that driver has backed into proper dock location and that all safety procedures have been applied to the vehicle and trailer.

h. Ensure product integrity, record temperatures of trailer from unit, determine product temperature, and document appropriately.
i. Inspect for damage and spoilage.
j. If damage is observed, follow generally accepted warehouse damage procedures or specific customer requirements. Note all damage or spoilage on bill of lading. It is also recommended that pictures be taken of the damage and attached to documentation.
k. Remove product from container in a safe manner.
l. Scan product if applicable or note product ID and count on warehouse receiving form.
m. Document date, time, temperature, signature, box count, and damages or other discrepancies on bill of lading.
n. Give driver original bill of lading annotated to reflect temperature, discrepancies, and amount actually received.
o. Ensure product is configured for warehouse putaway procedures.
p. Record location of any damaged product along with customer instructions for disposition.
q. Post receipts.

2. Placing Product in Storage or Staging Area

The final step in receiving is the placement of product in a permanent storage location. When the storage location and putaway process are systematically controlled, the need to move product from one area to another is substantially reduced, and the efficiency of subsequent retrieval and shipping is greatly increased.

a. Put product in assigned warehouse locations.
b. Note or scan location on storage form and return paperwork to assigned location.
c. Notify warehouse officials in case of product damage during storage operations.

Sometimes warm or chilled product will come into the warehouse needing to be blast frozen before being placed into storage. If the warehouse has a blast operation, a plan for blast removal based on freeze time should be maintained.

2.1 Placing Product in Blast Freezer

a. Load product in blast freezer as quickly as possible.

b. Ensure the product is properly prepared for blasting—remove plastic wrapping, insert spacers, divide product if necessary.
c. Ensure blast unit is loaded evenly for optimum freezing.
d. Ensure blast unit is turned on immediately upon loading.
e. Ensure quality control tests are preformed consistently to maintain product integrity.
f. Document times, temperatures, and employee's ID.

2.2 Removing Product from Blast Freezer

a. Take two temperature readings from the middle of pallets from each blast unit and record on blast compliance document.
b. Ensure completion of product freezing.
c. Put product in assigned location.
d. Note location on storage form, or scan in if applicable, and return it to office.

e. Frozen foods going into separate staging areas for order assembly should be moved out promptly unless the staging area is maintained at a reasonably uniform temperature of 0°F (-18°C) or colder.
f. As many operations as practicable (casing, palletizing, etc.) should be carried out in the cold storage area to reduce heat gain and associated quality deterioration.

3. Withdrawing Product for Shipping

Order picking is the process of removing product from storage in accordance with the customer's needs. This is, perhaps, the most basic service provided by the warehouse, and the function around which many warehouses are designed.

a. Office receives customer instructions and prepares documents for withdrawal and loading of product.
b. Office prepares bill of lading and enters all necessary information.
c. Pull product from lot or location as specified on withdrawal sheet and note count.
d. Put product in assigned location—dock, staging area, inspection room, etc.
e. Check temperatures, lot or product numbers, product codes, descriptions, and rotation dates, as needed.
f. Perform other steps as required (wrap, weigh, stamp, etc.).
g. Load the trailer as prescribed by the customer or driver per load sheet.
h. Scan or document as appropriate on truck loading sheet and verify count.
i. Report any damage to supervisor.
j. Seal container if required. Ensure driver or customer signs for release and note any seal numbers on documents.
k. Return shipping documents to assigned location and forward all required documents per customer requirements.

4. Customer Assurance

Even if everything is done flawlessly, communication with the customer and prompt follow-up are important ingredients of successful customer relationships.

a. Establish an inventory verification policy with customer.
b. Ensure proper and accurate billing is performed for services per contract or customer agreement.
c. Reconcile discrepancies with customer.
d. Coordinate shipping and receiving appointments.

The Changing Role of Warehousing

Arnold Maltz

Warehousing is, and will remain, an important part of the supply chain. But the need to minimize inventory and maximize the value of information changes the rules. Forty experts were asked to think about the future of warehousing. Their comments point to the following keys to future warehousing success.

1. The fundamental advantage of the warehouse is its flexibility to be customer-driven.

Successful warehouses are able to respond to any reasonable customer request, and do it promptly and well. The combination of open space under roof, relatively low cost labor, and entrepreneurial management is very attractive to supply chain managers. Firms are shifting activities among supply chain members to optimize total chain performance. The warehouse's flexibility makes it a good candidate for many of these new assignments.

2. Successful warehouses understand their place in the supply chain.

Inventory reduction is a primary goal of supply chain management. Another is better customer service, and a third is cost reduction. Successful warehouses, whether public or private, believe they have to contribute to all three objectives. Their emphasis is on improving product flow, thus increasing velocity and reducing inventory levels. These warehouses assume responsibility for continuous service improvement, especially in areas such as order accuracy, cycle time, and responsiveness to special requests. Finally, these warehouses are proactive in suggesting and leading process improvements. They realize that cost reduction is an ongoing imperative, and they share their operations expertise willingly to that end.

3. Successful warehouses are building on traditional roles to broaden capabilities and offer complete customer solutions.

Warehouses fulfill several roles in traditional distribution systems. They store goods that are produced or gathered in anticipation of sale. This storage role makes long production runs economical and better matches demand to capacity. Warehouses receive large shipments from several sources and make up shipments to multiple customers. This consolidation role reduces transportation cost for the whole system. Warehouses track inventories and adjust product to final customer specifications. This customization role, often called postponement, minimizes inventory cost and maximizes the ultimate customer's satisfaction.

Innovative warehouses are building on these strengths. They are using their highly flexible physical plant and labor force to go beyond customization to full-blown manufacturing, return processing, repair, and other product-related services. Warehouses are leveraging their knowl-

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edge of transportation to smooth the supply chain flow, decrease cycle time, and improve the distribution system's cost structure. Warehouses deal with delivery customers and products on a daily basis. Advanced warehouses learn from experience and become knowledge centers for the whole supply chain. Some even use their knowledge of delivery customers to become marketing support for their good clients. The physical appearance of the warehouse and the attitudes of personnel are an integral part of the service offering for many third parties and distributors.

This comprehensive knowledge and operational capability allows warehouses to become supply chain coordinators, usually at customer request. Packaging premiums and products together for promotions, building and stocking special displays, installing complicated product, coordinating continuous replenishment programs—all these are now handled by the warehouse in many cases.

The future of warehousing is some combination of traditional and emerging roles, depending on the economics of the industry and the individual customer. These roles are summarized below.

Traditional Roles	Emerging Roles
Storage	Flexibility
Consolidation/Transportation	Supply chain coordinator
Inventory tracking and management	Knowledge center
Customization	Marketing support

4. Successful warehouses plan to improve both service and cost performance indefinitely, because that is what their customers expect.

Warehouses are coming under the same "zero defects" edict as other supply chain participants. On-time service, inventory and order accuracy, and fill rates are now often over 99 percent. Same day shipping is a third party mainstay. Warehouses are upgrading systems, people, and processes to attain and hold these levels in the face of more varied delivery requirements and shorter order cycle times. Meanwhile, cost pressures remain intense.

Warehouse professionals are increasingly proactive in their relationships with customers, delivery clients, and supply chain partners. They are educating customers in the true cost of high service and suggesting process improvements. They are participating in joint sales calls with delivery clients to understand exactly what is necessary for cost-effective customer satisfaction. They are working with carriers, systems vendors, and suppliers to take cost out of the supply chain at every level.

5. Although location remains important, knowledge, systems, and relationship management are now the critical determinants of warehousing success.

Manufacturers serving mature markets are cutting the number of stocking points. A national network now consists of 2-3 plants and 3-5 distribution centers, on average. Distribution centers are located near large population centers, and cross-docks or carrier consolidations replace previous warehouse locations. Physical facilities are designed for optimal flowthrough as opposed to extremely efficient storage.

The successful warehouse moves inventory through quickly and without errors. Stored goods and crossdocked material are combined on a routine basis. Special customer requirements such as packaging, labeling, and light manufacturing are business as usual.

The new warehouses are larger, because they have to cover more territory. They are more complicated, because services are more customized. They are equipped with radio frequency equipment, bar code capability, and Warehouse Management Systems to handle high transaction volumes. EDI (electronic data interchange) is a given, and specialized handling equipment is installed for selected products.

Warehousing professionals are managing these newer, larger operations as part of the supply chain. They have put in place relationships with carriers and shippers to smooth the flow of goods through the warehouse. They have worked with shippers to improve product knowledge and receivers to understand delivery requirements. They are adding systems expertise as quickly as possible. In many cases customers are adopting the warehouse's system. Some warehouses still have terminals from multiple customers that they must feed separately, but that is changing rapidly.

6. Successful warehouses know no limits in what they can do for their customers.

A warehousing operation is space, location, people, and knowledge. Professional managers combine these resources to provide almost any service the customer requests. In addition to "normal" services, warehouse personnel have taken responsibility for equipment maintenance, site security, real estate management, building design, and stock room management at customer request.

This research was designed to find out what warehouses can and should do in the new world of supply chain management. Early on, one industry leader answered the question both elegantly and succinctly.

Q: What should a warehouse do? **A:** Anything that needs a roof!

That message of unlimited possibility is fundamental to the successful operators who contributed to this research.

Basic Warehouse Exposures

Connie M. Phipps and Joe Howard

Introduction

Our goals in this chapter are to help you identify basic exposures to loss to a public refrigerated warehouse and become familiar with various loss prevention techniques currently in use by refrigerated warehouse operators.

Loss exposures have three elements:

- The item subject to loss
- The peril(s) that might cause a loss to the item
- The financial consequences of a loss if it occurs

Loss exposures can give rise to four types of loss:

- Personnel or human loss
- Liability Loss (product of customer/slip and fall, etc.)
- Property loss of the warehouse
- Loss of Business/Business Interruption

The terms "peril" and "hazard" are often used when discussing loss exposures. A peril is a cause of loss. Fire, theft, collision, and flood are examples of perils that cause property losses. A hazard is anything that increases the likelihood of a loss or the possible severity of the loss. Hazards need not relate to a specific cause of loss. A general attitude of carelessness creates a hazard because it increases the likelihood of loss by many different perils.

All warehouses face the possibility of accidental loss. Each individual operation must decide to assume certain risks and to avoid others. Risks can be reduced by a variety of loss prevention techniques including safety programs.

Safety programs commonly used by warehousing operations include:

- Temperature probing/monitoring/receiving
- Ammonia safety and response procedures
- General maintenance and housekeeping
- Crisis management plans

- Forklift safety training
- Adverse Weather Drills
- Fleet Safety
- Employee Training
- Food Safety
- Personal Protection Equipment Safety
- Drug Testing
- Business Interruption Planning and Issues

Personnel or Human Life Exposure

The most important exposure to your operation is human life. Various government and state laws dictate the proper procedures for the safety of human life. These procedures should always be adhered to. The financial consequence cannot be determined, and human life cannot be replaced. Once again, the perils are many.

If a forklift operator is driving around with forks elevated after product has been stored, numerous accidents can happen. An ammonia line could be ruptured exposing employees to ammonia. Another employee could be hit with the forks causing loss of life or serious harm. Product could be knocked over causing harm to the employee.

Various employment practices relating to the treatment of employees may also cause personal harm.

Warehouse operators must be certain that safety programs are in place and up to date to afford a safe workplace. Compliance with these safety programs should be ABSOLUTE. Noncompliance should never be tolerated.

An employee handbook can be made available to all employees stating the practices and procedures set by your Human Resources people. (See also Employment Practices Liability.)

Customer's Product Exposure

This exposure increases with the amount of product stored, the type of product stored, and the various freezing techniques required. The item at risk in this exposure is your customer's product. The financial consequence of loss or damage to the customer's product could be quite substantial. The perils are many.

A warehouse could be found liable in any of the following situations:

- Ammonia leak caused by forks penetrating an ammonia line
- Poor maintenance of refrigeration system causing an ammonia leak
- Improper blast freezing

- Freezing at a temperature other than that requested by customer
- Contamination of product by other product stored
- Disappearance of goods
- Breakage of product
- Theft of a loaded trailer

Keeping records is an absolute MUST in this particular exposure. Should a customer claim the warehouse operator damaged the product, the operator must have written proof of the condition in which the product was received – i.e., temperatures taken upon arrival from the back, middle, and front of the trailer. Records must be kept of the storage temperature, what room the product was stored in and the temperature of the product when it left the warehouse.It is extremely important that the warehouse keep their own records in case of a legal claim. If you are using the inventory system of one of your customers, then you must be keeping duplicate records for the warehouse. Could you provide written proof that care had been provided for the product if a claim went to court?

Safety programs need to be in effect and practiced on a daily basis. Do you know who is in your freezers at all times and are strangers questioned if on premises? Do you run audits on your operations to insure that proper procedures are being followed?

Safety programs commonly used by warehousing operations include:

- Temperature probing/monitoring/receiving
- Ammonia safety and response procedures
- General maintenance and housekeeping
- Crisis management plans
- Forklift safety training

Warehouse Property Exposures

Buildings, vehicles (including forklifts), computer systems, refrigeration systems, racks, and other property owned by the warehouse are items exposed to damage or loss. The financial consequence from loss could be minimal or it could be the entire replacement value of the property in question. Other financial consequences could be the loss of business/customers and/or the interruption of business if the operations were shut down for any time period. Extra expenses involved in getting the operation up and running again after a loss would need to be considered. Perils could include fire, lightning, explosion, wind and hail, earthquake, flood, theft, vandalism, sprinkler damage, weight of snow, ice, or sleet, etc.

Fire smoke alarms, sprinkler system alarms, ammonia alarms, security of premises, and any other forms of fire suppression will all help reduce property losses. Programs should be in place and in practice to insure the safety of your employees and premises should property be in jeopardy or an ammonia leak occur. Familiarizing your local fire department with your operations will make them feel much more effective in the event of a loss.

Safety programs should include periodic inspections of premises for obstructions, slip/fall hazards, potential falling objects, forklift driver training, and ammonia safety and response. These safety programs should be reviewed at least twice annually and even more often if you have any physical change in your facility.

We do not see many General Liability losses in the refrigerated warehousing industry. Visitors should never be allowed alone on the property, and the amount of human traffic through a refrigerated warehouse should be very minimal.

Loss of Business/Business Interruption

Loss of business as a result of a disruption of operations can be devastating to business'. This is often the most underestimated cost of a catastrophic event which causes the shut down or a significant reduction in capacity to do business. Warehouses are encouraged to practice, and have readily available, disaster recovery and crisis management plans. These plans aid the business in quickly addressing critical emergency situations involving the loss of life, property, power and business continuity. Through thoughtful planning and evaluation, a warehouse can have plans in place to replace power, arrange alternate storage for customer's goods, assure life safety for employees and the public in general, and significantly reduce the down time for the operation. These plans are vital to the survival of the business and the continuation of employment for everyone.

Crisis Management, or Business Continuity Plans as sometimes called, work hand in glove with the Safety Committee's responsibilities for the safe operation of the Warehouse. A warehouse which has proper housekeeping, maintenance, security, refrigeration engineering (complying with the Process Safety Management Standard as well as RMP) and product handling process' are much less likely to suffer a loss and will be better prepared to address emergency situations after they occur.

It is everyone's responsibility to assure a safe working environment and proper maintenance and housekeeping.

Conclusion

In conclusion, a warehouse employee should always be cognizant of the fact that the money the owner may have to pay out for losses must come from somewhere. Whether it is salary increases, holiday parties, employee benefits, or other areas, the employee will ultimately share in the financial loss. The more you can do to recognize exposures and do your part to keep a loss from happening, the more profitable the operation will be and the happier the employees. Loss can be devastating in any form.

The next time you enter your operation, look overhead for any damaged pallets or loose product, check for any blocked aisles, pick up the broken pallet piece from the floor, KEEP THOSE FORKS DOWN, and take those temperatures and document them in writing.

ONLY YOU CAN PREVENT WAREHOUSE LOSS!!!

Operations Technology

Len Ebersberger

Introduction

The public refrigerated warehousing industry is beyond evolution—it is in revolution! Hardly a day goes by when customers don't ask the warehouseman to perform or provide new services which require more employee training and greater dedication to the job. Change is the only constant the PRW industry knows. Ownership changes, customers change, increasingly difficult tasks are expected, greater productivity is demanded, and employers are often required to draw from a less educated labor pool. To complete today's tasks, the industry must hire any warm body and train those people to be excellent employees and become assets to our companies.

Today, knowledge is gathered from whomever, wherever, and instantly packaged to meet ever changing, fickle customer demands. Our greatest asset is human imagination and dedication. We have to be quicker, more accurate than the competition. Customer inventory information must be up to the minute. There are more frequent, yet smaller orders, and the customer expects to be able to change those orders on a moment's notice. We are in the age of unbroken information flow that requires more value-added services in a time of expected low productivity because of the shrinking labor pool. Today's PRW must be able to receive, pick, and ship orders in a 4-6 hour window. Then we must track the delivery to ensure that the customer's customer received the correct products ordered.

Peter Drucker has stated, "Every organization has to prepare for the abandonment of everything it does." I would say, "Every PRW has to be prepared to change every current method in order to be more accurate and productive in the future." We require more intellect and more imagination in performing our jobs, or the customer will find other methods to accomplish his goals. If you do not change, the world will force you to change or go out of business.

Today's PRWs compete on the basis of five elements: quality, service, time, trust, and costs. It seems everything gravitates to the latter—costs. Yet most long-term business relationships have evolved around trust—trust that the PRW will get the work done in time and accurately, day in and day out. Today's PRW needs to be effective—doing the right things. It also must be efficient—doing things right.

Customers are pressuring for more elements of distribution to be controlled by the PRW. We must utilize EDI (Electronic Data Interchange) and Internet communication connections to be able to minimize receiving times, order entry times, and order confirmations. E-commerce is rapidly replacing the conventional EDI transmissions. Information exchange must be accurate and up-to-the-minute. Customers demand information on a moment's notice. Customers want to see productivity gains. In 1972, the grocery industry was picking orders at the rate of 134 cases per hour. In 1995, the rate was just 10 cases more per hour at 144 cases. Building costs have increased and investment rules have changed. Accuracy, response times, and errorless orders have become the expected normal operational methods.

The use of Extensible Markup Language (EML), a method of exchanging supply chain messages over the Internet, will become commonplace. This language uses standard definitions as the language of e-commerce. It will replace EDI and open access between small suppliers and large customers. EML requires special message tags to identify the various types of messages. It then directs the tagged message to the appropriate computer application to be acted upon.

For EML to be effective, trading partners and the various food industry groups must reach an accord on definitions. This is future technology that could give the information directly to the person who requires the specific data.

Cross Dock Operations

Cross docking is used to increase efficiency and accomplish product distribution goals. It is time sensitive. Crowding your dock with cross docking products that are waiting longer than 6 hours to load will decrease your dock efficiency. To qualify as cross docking, the items must be scheduled to ship immediately and not put away for short time hold. The orders must be predictive and move as a unit. Information on what orders to send the crossdocking materials with must be uniform and readable by all handlers. ASNs (Advance Shipping Notices) must be incorporated by the partners to minimize order checking.

In order to qualify as cross docking, two or more of the following elements must be present:

1. Product arrives—you know the destination.
2. An order is waiting for the product.
3. You ship fewer than 200 locations per day.
4. Throughput is more than 2,000 cases per day.
5. More than 70% of product is case select.
6. You receive pallet load quantities of each cross-dock shipment.
7. Incoming products are labeled for cross-dock shipments.
8. Merchandise is time sensitive.
9. Storage space is tight.
10. Merchandise is special ordered.

Many customers see cross docking as a way to solve their inability to manage inventory to their customers. Cross docking becomes a method to correct production errors and inability to manufacturer to customer requirements in a normal time frame.

Some of the trade services we see being required are:

- Next day delivery
- Responsiveness
- Single point of contact
- Direct store delivery
- Fast receiving/shipping
- First pass fill rate over 95%
- Support customer pick up programs
- Emergency orders

Bar Coding

Bar coding is a mini data file that converts symbols to readable data. It is an extremely accurate and reliable method that allows the user to gather important data quickly and in greater formats than before.

Why is bar coding becoming so important to your company? When used in the proper warehouse information system, bar coding enables companies to achieve better customer service levels. It can reduce inventory, accumulate more accurate shipping information, improve accu-

racy and warehouse productivity, and force disciplined warehouse product location and proper rotation.

The system basics include:
1. Optical scanner
2. Communications terminal—mini computer keyboard, voice, or keyed entry.
3. Radio receiver
4. Radio transmitter
5. Converter
6. Interpretive software

Our challenges to date in the PRW industry are problems similar to the early EDI problems. There is a lack of standardization between system users. UCC 128/39 is the code that won early; however, 2D bar codes (PDF 417) with more information may quickly become the code of choice. 2D bar codes allow 2,000-3,000 characters per square inch of tag space.

Other bar codes to be aware of are:
1. **Aztec**—limited to 1,914 bytes of data, capable of both alpha and numeric character use
2. **Micro PDF 417**—utilizes maximum data condensation
3. **"Super Code"**—freedom in formatting, can use up to 4,000 alphanumeric or 5,097 numeric characters
4. **Aztec Mesas**—can be combined with standard bar codes
5. **RSS-14 Reduced Space Symbology**—holds 14 digits of information, or 34 in stackable mode. Combines linear and 2D technology. Attaches other information to UCC like sell-by-dates. This code can be used as an ASN. An example of this technology is attaching purchase information to retail "loyalty cards." Then in the case of a product recall, the retailer will be able to notify all customers who purchased the affected products.

Also, equipment, scanners will become more flexible in bar code interpretation and will be able to handle more than one type of bar code.

Advantages of using bar codes include:
- Improved on-time performance
- Lower error rates
- Reduction in cycle times
- Increased inventory turnover rates
- Removal of human omission errors
- Improved truck loading and unloading times
- Reduced claims
- Improved warehouse equipment utilization
- Allowance for the use of digital cameras to record shipping condition or damaged goods, etc.
- Better information sharing capabilities
- Ensured proper product rotation (FIFO or priority)
- Help in identifying cost drivers
- Increased productivity

Supply chain partners must be able to support processes with timely, usable data, which then becomes actionable information. Great customer service is the ability to anticipate potential problems like a late delivery and react in time to allow the problem to become no problem. PRWs are taking on more responsibility for clients' logistics activity. Therefore, connectivity,

visibility, and optimization become real components of warehouse systems.

Bar code systems, when combined with WMS (Warehouse Management System) software, create opportunities for increased productivity. A WMS will allow for the use of the system for:

- Location system
- Weight taking
- Pallet receiving—ASN (Advance Shipping Notices)
- Computer generated pick replenishments
- Directed order picking
- Determining the best shipping configuration
- Productivity tracking
- Scanning versus keying in information
- Paperless warehouse operations
- Shipping accuracies of 99.5% or better

Some other bar coding functions can be accomplished without a WMS. These include:

- Capturing weights and downloading the information
- Tying pallet identification (PID) tags to a scannable location
- Manual entry order picking
- Order pick verification at the dock
- Inventory counting by PID and location
- Information will be off line rather than real time

Bar Code System Components

1. **Software**—instructions that tell the computer how to work. Very few software vendors know how to handle the refrigerated warehouse product date sensitive product requirements.
2. **Hardware**—
   a. **Scanner**—an infrared device used to scan bar codes
   b. **Data collection device**—mini computer terminal which communicates with the host computer
   c. **Controller**—device mounted in the ceiling of the warehouse used to collect the transmitted data and forward information to the host computer, usually located in the office area
   d. **Host computer**—computer that manages information that is collected in the warehouse and returns commands to operator based on the information required in the software program
   e. **Innovations to watch**—scanners attached to fingers and the back of the hand. Computer and operator communications via voice rather than readable data. Completely wireless warehouse management systems.

Radio Frequency Identification (RFID)

RFID tags allow two-way communication between the RFID tag and a scanner. It works in the 2.46 GHz radio frequency range. The tags can be programed and will provide more information on the tag. The RFID tag has a chip, antenna, and substrate. It is not limited to line of sight. The data can be changed 100,000 times and it contains up to 1,000 bytes of memory. The tag is passive and requires no batteries. They are powered by external radio waves. The system can record 50 items per second using a common application program interface.

The major change for PRWs is the addition of Micro Electro-Mechanical Systems (MEMS) which will allow RFID tags to detect and record temperature changes with a time and date stamp. The reason for using RFID tags is to gather complete information on supply chain activities and integrate best business practices between partners. Additionally, customers want improved processes to meet their increasing exposure to mistakes and expectations.

RFID systems need defined product flow and processes. They will be used on products of value or critical to the health and well being of the ultimate customer. Finally, RFIDs will be used on products of high value and requiring security like shrimp and lobster.

Paperless Warehouse—Fact or Fiction?

To satisfy today's customer requirements, PRW operators must increase productivity while cutting order pick and inventory errors to zero. Warehouses that have successfully installed WMS software have seen dramatic productivity increases and error reductions. However, the systems' cost for hardware and software is substantial. To realize major productivity gains, a warehouse must have a large enough workforce to support the investment needed for a WMS. Now available from some WMS vendors are methods that allow new installs to pay and have the system maintained on a monthly fee basis. These are called Application Supply Providers (ASP).

WMS systems are expensive to buy, expensive to train operators for, and expensive to install. Also, discipline is required to best utilize the system components. One critical factor a PRW must have for its varied customer base is flexibility. However, WMSs do not respond well to flexibility. They work extremely well in a rote, continuing, repetitive functioning environment.

Mispick errors are, usually, one of four types: incorrect count, product code substitution, product completely missed, and not ordered items being sent to the final customer. Every mispick causes a major problem when you are responsible for someone else's inventory. The high cost of mispicks includes shipping the wrong items, customer complaints, return shipping costs, restocking, re-picking the correct item, reshipping, and delay in payments. The paper work alone has been estimated at $25.25 for a mispick error.

With a Warehouse Management System, service time to the customer usually improves by 50%. Order fulfillment increases from 92% to 99.9%. Warehouse direct labor costs can be cut in half and productivity doubled. Density in storage capacity increases due to real time product availability. Inventory is received quicker and made available as soon as it is put away and scanned to a warehouse location. Full inventory counting is eliminated due to the cycle counting function. (Most WMS systems require cycle counting on any items that have a pick error. This occurs on the next cycle count, perhaps when the very next picker reaches the pick slot.) Order turnaround time is reduced from 72 hours to 4 hours or less. On time deliveries increase from 90% to 99% because the shipments leave the warehouse on or ahead of time.

For peak WMS performance, these steps must be followed:

1. Bar code labels are placed on every case by manufacturer or co-packer.
2. Pallet identification labels (PID) are placed by shipper to match up to shipping manifest from the plant. This allows the best use of Advance Shipping Notices (ASN).
3. PID are scanned at the warehouse and put away notice sent to pallet jack operator.
4. Product is taken to location and location is scanned to verify correct put away.
5. Product is now available for the next wave of replenishments or order picks.

6. Wave releases one order or multi-truckloads of products.
7. Each pallet, full, or multi-case pick, is a suborder and may be picked by more than one warehouse person.
8. Computer directs suborders either to a pallet jack for case selection at floor level or to a forklift for full pallet picks in the air.
9. Completed pallet is taken to stretch wrap station for a pallet manifest, which lists all products and quantities on the pallet and also includes bar coded shipping door location, pallet detail, and truck load number.
10. Pallet manifest order number is scanned and door number is scanned upon loading. This is matched to the truckload number and verified.
11. Bills of lading and customer invoices are printed and given to driver at dispatch time.

The cost to purchase software and hardware, train employees, and modify a packaged system can be as high as $1,000,000. In order to justify this cost, the payback has to include large staff cuts and substantial reasons for this type of investment.

Successfully implementing WMS technology requires that your customers be included in the process early and that you have a complete understanding of their requirements. Operational personnel must be included in the system modifications and development. Understand that this system will require complete reorientation of your entire staff. The pace of adaptation will be slow at first. The system will add a variety of new, demanding disciplines to the work force. Stay flexible throughout the development functions. This will allow for the best system to match your requirements. Have a dedicated space for the development functions. Also consider an in house person whose sole responsibility is the system development. Some WMSs have been developed specifically for the PRW industry and require few, if any, software changes.

Be sure all current computer systems will integrate with the new WMS. Not all employees will embrace the new methods. Most long time employees will resist and must become system "champions." Lastly, remember this is a completely new system. Employees must be trained, retrained, trained, and retrained again to have a successful Warehouse Management System implementation.

Strategies for Successfully Implementing Technology

1. **Customer Awareness**—How well are you currently meeting your customers' expectations? If you are having problems with recurring bad performance and are an integral part of their activities, you may need to reevaluate your capabilities. Today's customer cannot be maintained if an adversarial relationship exists. You must know their long-term plans and customer satisfaction objectives. With our customers getting larger and fewer, it is essential to know their operations as completely as they know them. Do not expect to charge ahead and implement new technology without the key customers' input.

2. **Operations Planning**—Plans are developed which make the PRW a strategic weapon for absolute customer service. All key operations personnel are included in the system planning, review, and final test program.

3. **Training**—Lack of adequate training for system operators results in the greatest failure risk upon implementation. You can have the finest WMS and it will fail unless you train, retain, and train again every system user. More than 50% of new warehouse system implementations are stopped sometime during the system upload, and 16% are never restarted.

They become an over burden for the operating company.

4. **Understand Pace**—Technology will make your warehouse more responsive, less defensive. Also, system demands are greater and expectations higher. The systems make you work smarter and provide more continuous flow to the operations. Also, it is best to ramp up your new system in smaller bits. If you try to implement the entire system without a fallback position, you risk a disastrous startup.

5. **Add Variety**—Special customer requests may be part of the technology development process. Be sure the customer can internally support each and every request they make. Reconfiguring packaged software programs is expensive. If value added services are requested, be sure your company is getting paid for these services. The customer will want every bell and whistle he can get. It will cost your company more money, and you must get a return on this investment. Realize that each customer covered by the WMS may require special reports, system support, and procedures to fit into the new disciplined methodology. Select WMSs that allow easy and varied report generation.

6. **Flexibility**—Consider entire system objectives, equipment required for support, personnel capacity for change, hours of operation, and allowable shipping variances before committing to implementation of new technology. If technology restricts your ability to react to special requirements, then rethink why you are implementing these costly changes.

7. **Commit to Excellence**—Accept no excuses. It is necessary for everyone to do it right the first time. Inventory mistakes must be corrected as they happen, not later! Cycle counting is a way of life and the second most important warehouse function. Putting product away properly, proper product rotation, and date code adherence all become the operating norm. Good housekeeping with no off stacking permitted will help in this essential process.

8. **System Integration**—Your PRW is an important part of the entire cold chain. Every function must fit not only into your other computer systems; it must fit into the customers' systems as well. Your technology is part of an entire process of which your operation is a small, yet important part. We handle multi-dollar items for a few cents in revenue. It is absolutely essential we do not damage, lose, or mis-ship these items, or the thin profit margin will disappear.

9. **Space Utilization**—Expect higher throughput and greater warehouse slot utilization. Technology investments should only be made in high turnover environments. If you are in a commodity business, the payback will not occur in the technology investment. Random storage under a locator system will eliminate the need for assigned slots and product location by code.

10. **Order Picking**—A Warehouse Management System can handle a variety of layouts which will maximize order pick efficiencies. Z picks, U picks, picks from above the floor level, and crushability requirements can all be managed by the WMS. You can select the system to require case scanning or manual entry of number of cases ordered. The system will pre-route by activity, crushability, or quantities of pick. You can have a zone pick, batch pick, or wave pick for a single order or multiple loads. It is your system. Make it work to your advantage.

11. **Employees**—Training must become continuous. No company can "whip" productivity gains. The gains will come from proper application of the system and employees' understanding the specifics of the system. It is essential to success that all personnel know how

to utilize all the screens which may appear on their bar code device and how to toggle back to work functions. It seems that personnel want to experiment. This causes them to get into functions they do not need and they have not been trained for. They then press function buttons until they get out or lock up the device. Make it easy to get back to the start position.

12. **Automatic Identification**—Bar codes will standardize; however, pick a system that can adapt to new technology. Bar codes are the foundation for real-time computerized warehouse inventory and production control. Our customers will recognize standardization and system discipline as a must. Their systems will require the same implementation techniques for success.

13. **New Warehouse Systems**—The warehouse of the future will be operated in a paperless environment with all warehouse moves computerized for the best methods. The system will be interactive with the customer. The WMS directs, controls, measures, and reports activities that were once hard to quantify. They are essential to Account Based Costing (ABC).

14. **Reasons for Technology Implementation Failures**—With technology implementation, properly programmed and reviewed software is not usually the problem. Some systems are for show and do not produce any productivity benefits. Know going in what you want to accomplish. Some systems are solution driven, not requirement driven. Analyze your business and the customer requirements over and over to best understand what you want to accomplish. Systems fail because the initial requirements were unclear and not officially stated.

Remember, software changes are always late. Allow enough time to develop the software and to properly test before implementation. Once you gear everyone up to go live is, it is not the time to have software problems. Testing time should never be short-circuited.

Technology fails when you do not "freeze" the software design. At some point, you have to reach a comfort level that the software and its modifications are going to work. Stop at that point and retest to your expectations. Do not keep adding to the requirements after you go live. Train, retrain, and retain again. If the people operating the system do not know how to make it work, you are doomed to failure. Train using real warehouse data and situations. Finally, top management must be involved throughout the project. Without this ongoing commitment, the system will be picked apart before the benefits can be realized.

To be successful, design for flexibility, efficiency, and effective space utilization. Eliminate empty moves with material handling equipment. Select material handling equipment that streamlines the flow of materials. Integrate information systems that provide accurate, timely data with the material handling equipment. PRW operating systems will change. Those companies that follow the cutting edge technology closely, adopt, modify, and change their complete systems will be the winners in the 21st century.

Soft Technology

Warehouse Design

Ceiling heights continue to move upward. The cost to add a foot of height to a building is about $1.00 per square foot (about $35 per m2 to add 1 m of height). Ceilings to 44 feet (13.4 meters) clear are in use today with conventional material handling equipment. Keep your racking flexible to service your multiple customer requirements. Review how your business may change and understand the impact on your business. Will the storage be long-term or order pick?

Aisle Widths—Very narrow aisle or regular aisle widths? Very narrow aisle equipment operates in a 5'6" (1.7 m) width. However, if the customer requirements are variable, you will not be able to successfully operate more than one piece of equipment in the narrow aisle. The specialized equipment may run up to $100,000 per piece. With regular narrow aisle equipment, you can add more equipment to any aisle as required by customer orders. Flexibility is the key to future success with the customer base. Build for tomorrow's business, not just today's.

Dock Widths—40' (12.2 m) has become the standard; however, more docks are being built as 50' (15.2 m) wide to accommodate stretch wrap equipment, tilt tables, cross-dock activities, and staging space. Temperatures should be close to 33°F (0.6°C) with lower temperature preferable.

High Rise Warehouses—The height at which a warehouse becomes "high rise" is getting blurred. Usually, heights above 45' (13.7 m) are recognized as high rise. They have very specific uses, are expensive to operate, and require support systems like mezzanines, sortation equipment, and mechanical loading equipment. They have a lower per cubic foot cost to build, but the maintenance is higher and the equipment more expensive. They are very expensive to reconfigure and impossible to reconfigure if the building is rack-supported. High rise warehouses are, generally, not flexible for PRW usage. However, if the building is for a single, specific customer, this may be an option to explore.

Rack Designs

Analyze your business. If possible, keep all top levels the same height and equal clearance to the ceiling deck. As an example, 288" equals four 72" openings or three 96" ones. In a heavy order pick environment, consider raising the floor level rack position 12" (30 cm) off the floor. Always design for 1" (2.5 cm) overhang on all pallet sides. Review the net openings with supplier. Certain cross members may infringe into the net opening space.

Two Deep Reach vs. Very Narrow Aisle Single Deep—Always keep flexibility in mind in rack design. Two deep reach offers flexibility with space utilization. The combinations and flexibility two deep reach racks offer give greater long-term benefits than drive-in or very narrow aisle single-deep racks. Drive-ins can be used for specific customers who require full truckload quantities for storage. The depreciation schedule for racks is 7 years. Therefore, flexibility is more important than specific immediate need.

Push Back Rack—This type of rack is excellent for over aisles and top rack configurations. The cost is $125.00 per slot versus $60.00 per slot for conventional racking. They require higher net openings. The newer push back racks operate in the cold storage environment without undue problems. They can be used in blast cells also. Push back keeps the product flush with the aisle and can go up to 5 deep in a freezer.

Pallet Flow Rack—An excellent choice for heavy order picks of less than 100 Stock Keeping Units (SKUs), with ease of operations for multiple pallets of back up stock. Helps keep excellent product date code rotation and first in, first out rotation. Difficult for full pallet selection, if required. The cost is $100.00 per slot versus $60.00 per slot conventional. Pallet flow also requires a higher net rack opening because of the roller rails used to carry the pallet. The system requires "A" grade pallets with no bottom boards missing. You gain density of pallet positions, more facings than drive-in racks.

Mobile Racking—Costly; slows operations. Works best in lowest revenue accounts, those with

long-term storage and low turnover. Best use in areas with high land costs. Offers excellent density in the warehouse as single deep racks are closed up until needed to re-stack or to remove inventory.

Material Handling Equipment

The PRW industry has been slow to adopt forklifts as a vertical movement piece of material handling equipment. Pallet jacks work better and quicker for horizontal movements.

Turret Trucks—Mobile stacker cranes on wires. They can operate in very narrow aisles and handle large quantities of order picks in the man-up mode. They have a fixed number of pallet moves per hour and you cannot add more units to an aisle to move more pallets. They are expensive, $100,000 per unit

Narrow Aisle Reach Trucks—Speeds of 7.5 miles per hour (12 km/h) loaded and lift heights exceeding 400" (10.2 m). Lifting speeds are around 100 feet per minute (30 m/min). Work in ten-foot (3-m) aisles for best operations.

Best Combination—Narrow aisle reach trucks for lifting and lowering; high speed riding pallet jacks for transporting. This gives you speed, versatility, flexibility, and best economic value. Sit down equipment can be used for truck loading and unloading and for bulk storage situations.

New Trends

Heated freezer suits are available now, though the price is in the $2,000 range per copy. They are excellent for blast freezer operations, ice cream environments, and other extremely low temperatures and may be necessary to attract the next wave of new employees.

Voice recognition is available now and will be the way to operate your warehouse in the very near future. With the bulkiness of the clothing in the PRW industry, this will be the preferred way to communicate.

Industry Technology Trends

1. Heated freezer suits attached to the forklift battery. Excellent for sit-down and blast freezer work areas. Expensive—about $2,000.00 per suit.

2. **Intelligent bar code labels**—Bar codes with a chip the size of the head of a pin. The memory device can store, retrieve, and change data. The label chip handles 1,000 bytes of memory and has a small antenna attached. The chip is passive and requires no power source. It is powered by the radio waves of the reader or interrogator. The chip now stores data, and we may see them as temperature and location monitoring devices in the near future.

3. **Wireless Application Protocol (WAP)**—A handheld device that will interface directly with the Web. This would allow real time inventory viewing by the manufacturer as the device is used in the warehouse. A protocol (standards) is being developed to use these devices.

Pallet Facts and Fundamentals

Steven L. Coon and Benjamin Milk

The motto of the National Wooden Pallet and Container Association (NWPCA) is "pallets move the world." As any refrigerated warehouseman knows, that's not much of an exaggeration. Pallets are both the bane of existence and a necessary element in almost every large refrigerated warehouse facility. Pallet failure can damage product, reduce efficiency, disrupt operations, and cause serious injuries. Nevertheless, pallets are used throughout most supply chain channels because they are efficient and they are compatible with most material handling equipment and racking systems. In the US alone, there are nearly two billion pallets in use each year. One billion of these have been used before; some 400 million are new; 250 million are repaired, recycled, or abandoned; and as many as two hundred million go into landfill. More than a billion board feet (305 million meters) of lumber go into pallet construction every year.

A 1999 survey of pallet suppliers in the US examined pallet orders and found that the 48 x 40 inch (122 x 102 cm) pallet is clearly the most popular size, accounting for about one third of all pallets. While the survey undertaken by NWPCA, the USDA Forest Service, and Virginia Tech indicated that the preferred pallet is 48 inches by 40 inches, it found a total of 428(!) different pallet sizes produced in the US. An informal survey of PRW operators concluded that the 48 x 40 inch pallet is, by far, the most commonly used pallet in the PRW industry. The 48 x 48 inch (122 x 122 cm) "drum" pallet and the Europallet (approximately 31½ x 47 in or 80 x 120 cm) are typically found in much, much smaller numbers.

Pallet Performance

Pallet durability is a function of two things: design and usage environment. Pallet design concepts, in particular, can be effectively utilized to improve pallet performance. Generally speaking, more lumber, denser wood, and better fasteners translate into stronger, stiffer pallets. The stronger and better fastened the outer member of the pallet (outside stringers and top and bottom lead boards), the more durable the pallet.

A study conducted many years ago by the US Forest Service provided design information that is still helpful today. Among other things, the study revealed that a 5% increase in the number of fasteners resulted in a 50% improvement in durability; that softwood plywood decks were nearly 50% more durable than comparable lumber deck pallets; that the use of hardened steel fasteners ¼ inch (6 mm) longer than corresponding stiff-stock fasteners improved pallet durability by almost 60%; and that deckboards made from air-dried hardwood lumber instead of green lumber could improve pallet durability by more than 40%. Pallet durability, in turn, translates into reusability, higher performance, longer pallet life, and decreased cost per trip.

Sometimes a simple design change can significantly impact the performance of a pallet. If you have any say on the type of pallets that come into your facility, these three well-known design principles will ensure that you are getting durable, cost-effective pallets:

1. Increased deckboard thickness is a more efficient way to affect pallet performance than increased width or coverage.

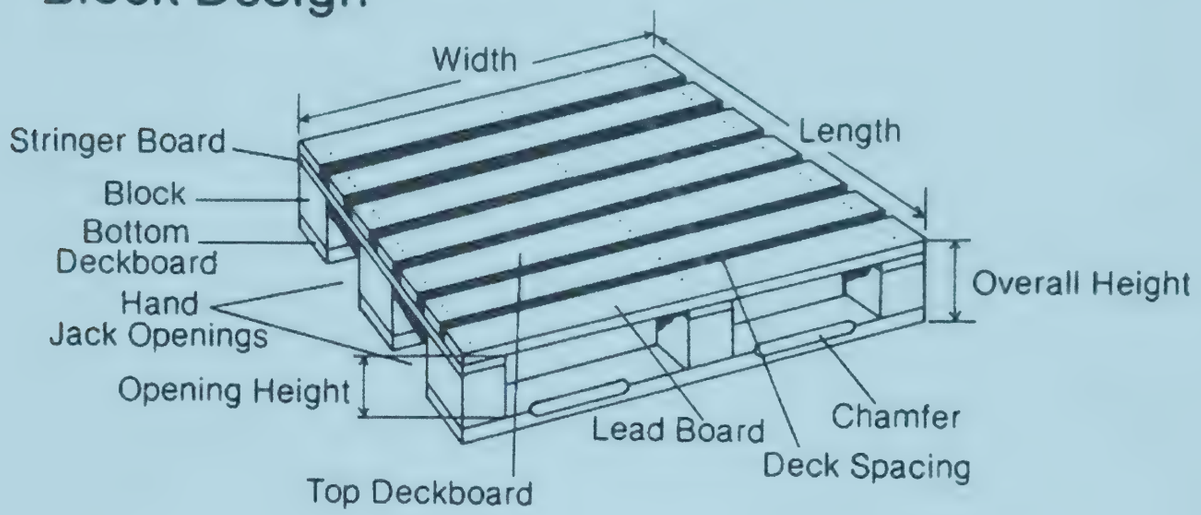
2. Increased stringer height is a more efficient way to increase stringer strength than increased stringer width.
3. Of all the characteristics of pallets, thickness and proper fastening of deckboards affect overall pallet performance more than anything else.

Accurately Determine Pallet Performance Needs

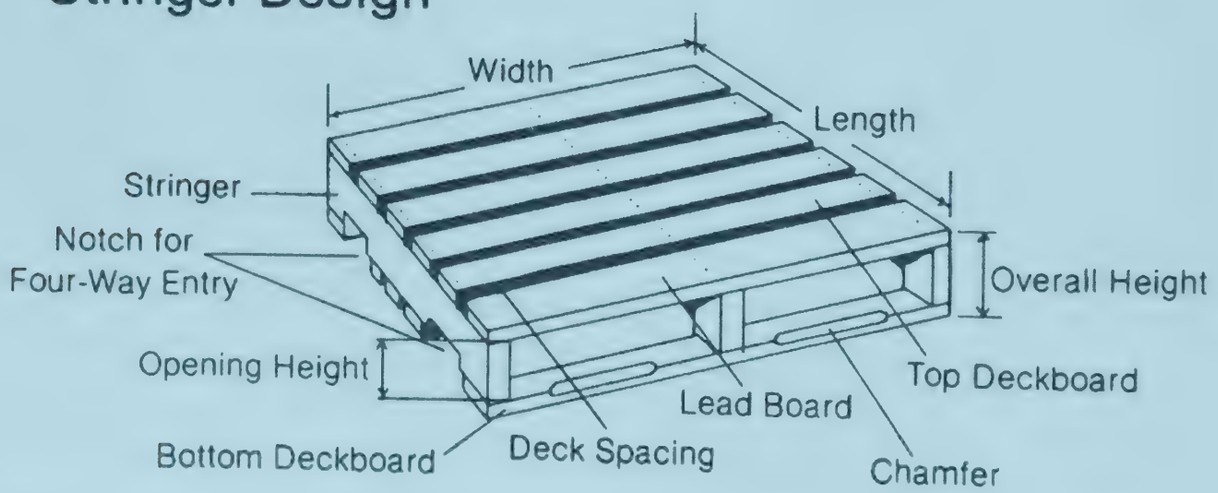
Pallets, like other load bearing structures, must be designed for strength and functionality. The NWPCA has developed a Pallet Design System (PDS) that can help determine the best possible design for any environment. The design process begins with determination of pallet performance requirements. (When the requirements vary for different pallets or unit loads, the conditions which most highly stress the pallet should be the basis for design.)

The questionnaire "Performance Requirements for Pallets" serves as a guide for determining performance requirements for pallets. The completed questionnaire can be used as a point of reference from which to discuss pallet requirements with suppliers.

Block Design



Stringer Design



The World Food Logistics Organization gratefully acknowledges the National Wooden Pallet and Container Association's permission to publish these drawings.

Performance Requirements for Pallets

Load Conditions

1. List the container types and objects to be placed on the pallet (bags, cases, bulk containers, barrels, blocks, machinery, etc.).
2. What are the maximum and minimum unit-load dimensions, not including the pallet? (length, width, and height in in/cm)
3. What are the minimum container or object dimensions by type in question 1? (length, width, and height in in/cm)
4. For each unit-load type (container or object type: bags, container or object size, footprint size), what are the maximum, minimum, and average load levels? (in lbs/kg)
5. List the type of load stabilizers used (shrink wrap, stretch wrap, adhesives, etc.) and the appropriate percent of bound or unbound unit loads.
6. Identify the unit-load types which incorporate pallet sheets, spacers, or unit-load caps.
7. For each unit-load, describe load binders used in transit.
8. Describe any product or package more moisture sensitive than untreated corrugated which will be placed on the pallet.

Support Conditions

1. Is the pallet to be placed into racks?

a. Describe the types of pallet racks in use (gravity feed, drive-through, conventional, ASR, etc.).

b. By unit-load type, what are the maximum and minimum unsupported free spans, racked across the length and width of the pallet.

2. By unit-load type, how many unit-loads high will pallet loads be stacked (maximum) in the warehouse?
3. By unit-load type, how many unit-loads high will pallet loads be stacked (maximum) in shipping?
4. By unit-load type, what is the maximum length of time a unit-load will remain in a rack or stack?
5. What are the maximum allowable deflections (in in/cm) permitted in pallets and pallet parts for each support condition (stacking or racking)?

General Handling Conditions

1. Will the pallets be handled using fork lifts? If yes, what is the range of fork tine length, width, and spacing between forks? Is the spacing between fork tines adjustable during handling?
2. Will pallets be handled with wheeled pallet trucks, walkies, AGVs, or straddle cars? What is the range in length and width of the forks, spacing of the forks, and lowered fork heights? (in in/cm)
3. Will the pallet be handled in a sling mechanism? If so, what is the width of the support bar and the bar spacing? (in in/cm)

4. Will the pallet be used on roller conveyors during horizontal transport? If yes, what is the range in roller diameters and roller spacing? Are the rolls parallel, perpendicular, or both with respect to pallet length?
5. Will the pallet be subjected to chain conveyance? If yes, what is the range in chain width (in in cm) and unsupported free span (in in cm) between the chains? Is pallet movement on the chain conveyor parallel, perpendicular, or both with respect to pallet length?
6. Will the pallet be used in automatic palletizers and pallet dispensers?
7. Is the pallet to be 2-way, partial 4-way (notched stringer), or full 4-way accessible to handling equipment?
8. Are there any sanitation or flammability performance requirements? If yes, describe these requirements.
9. What are the maximum temperatures to which the pallet will be exposed?
10. Is the pallet intended for a single use or multiple uses?
11. If a multiple-use pallet, what level of durability (in years) is desirable?
    a. How many handlings per trip are typical? (A handling is a single lifting, transport, and setting down of a loaded or unloaded pallet)
    b. How many trips per year are typical?
    c. What percent of pallets would be lost in the system?
12. Describe any other unusual situation which would stress the pallet beyond the conditions described in completing this questionnaire.

Miscellaneous Requirements

1. What is the maximum allowable pallet weight?
2. What is the range of acceptable pallet heights?
3. What is the range in acceptable pallet length and width?
4. Is the pallet to be repairable?
5. Is the pallet to be nestable?
6. By percent, coverage, list any minimum top and bottom deck bearing area requirements. (This will be a function of the stacking strength of the containers on the pallet.)
7. Are deck overhangs or wings acceptable? How much overhang is acceptable? (in inches)
8. Are openings required in pallet decks for ventilation?

Pallet Safety

Getting the right pallet is only one part of the warehouseman's challenge; it is also crucial to adhere to safe pallet practices. There are countless lawsuits today stemming from both the use of low quality or damaged pallets and the misuse of high quality pallets. Proper usage of well-built, well-maintained pallets can go a long way to minimize the risk of injury.

The UK Cold Storage and Distribution Federation and the Refrigerated Food Industry Confederation publish The RFIC Guide to Safety in the Use of Pallets, Pallet Converters, Palletainers, and Racking. According to the guide, accidents attributable to pallets arise from five major sources:

1. Poor design
2. Poor construction
3. Use of pallets designed for different loads
4. Use of damaged pallets
5. Improper handling

Accidents can happen in any environment. but warehouse managers can minimize the likelihood of pallet injury by following these recommended practices:

1. Select the right pallet for the job. Start with "safe" pallets—pallets designed to properly and safely carry the weight of a specific unit load. Quality pallets will minimize the risk of a pallet failure and resulting worker injuries. Try to use pallets that are built, maintained. and repaired to meet either the NWPCA national pallet standard or the American Society of Mechanical Engineers (ASME) MH1 standard for pallets.
2. Do not build or repair your own pallets. If you do. however. make sure that your craftsman uses tools like PDS and quality assurance programs like NWPCA's SPEQ (Specialized Pallets, Engineered for Quality).
3. Use only proper handling techniques. This is absolutely essential to minimize risk.
    - Inspect each pallet for damage prior to each use, and don't ever use pallets in need of repair.
    - Under no circumstances should any person ever stand, step, or lean on a pallet. A pallet should never be used as a personnel lift, or for any purpose other than its intended use.
    - Make sure unit loads are not stacked higher than specified.
    - Train your employees how to properly handle pallets.
    - Standardize the unit load to fit the pallet, and stabilize the unit load before moving.
    - Keep forks horizontal and enter the pallet carefully; put forks all the way in before moving the unit load.
    - Lower the pallet gently to the floor—never drop it.
    - Keep the unit load low when moving it with a fork lift or pallet jack.
    - Don't slide pallets on the floor, empty or loaded.
    - Don't ever pull a unit load from a delivery truck by hooking something onto the pallet and pulling it off the truck.
    - Stack unit loads straight within the footprint of the unit load itself and when you're stacking one unit load on top of another for storage or shipment.

Pallet Handling and Storage

Training warehouse personnel in the basics of proper pallet handling can pay for itself many times over. A properly trained forklift operator is not only more likely to avoid injuring himself or others, he is also more likely to avoid damaging product and racks. while prolonging the life of pallets and lift trucks.

- Operators should be taught to line up forklift and handtruck tines at a 90 degree angle to the pallet so that the tines enter the pallet straight on. Forklift operators should never push or nudge pallets with forklift tines (this puts stress on the pallet that can result in both pallet and product damage). Most pallet damage is caused by fork tine impact.
- Operators should lower pallets slowly and smoothly all the way to the ground instead of dropping them the last few inches. Pallets should also not be dropped from the top of stacks or tossed onto a stack. This can result in protruding fasteners. pallet damage, and, eventually, pallet failure.

- Idle pallets present a fire risk that cannot be ignored. Make sure that pallet storage areas are clearly delineated and that pallets are kept in a safe and orderly fashion and segregated from potential ignition sources such as electrical panels, cables, and maintenance areas.

Pallet Trends

The pallet industry, like most other industries in the 21st century, is undergoing massive change. Sooner or later, some of these changes will impact the way the refrigerated warehouse industry operates. Consider, for example, the following topics which are the subject of growing discussion in the pallet industry.

Pallet recycling—The recycling of wooden pallets has already had a great impact on the number of new wooden pallets being manufactured. Recycling has grown dramatically over the past twenty years, with annual growth rates of 20% or more. Recycled pallets may mean that fewer new pallets come into circulation, but a deteriorating pool of pallet cores will limit growth in recycling.

Rental pallets—This was unquestionably one of the most significant pallet market factors in the 1990s, and rental pallets will have an even bigger influence in the future. They will impact pallet sizes, the quality of pallet cores, and customer attitudes toward pallet ownership. Chep is the largest pallet rental company; the Canadian Pallet Council (CPC) is another large program which bears watching.

Pallet design—Wooden pallets may go through some evolutionary changes related to changing raw material markets. The Engineered Wood Products Association is pushing the use of panels as a way to extend pallet life. Composites of different types will be used increasingly. As the world shrinks further, the push to standardize around a single pallet size and type likely will gain steam. If this ever happens, it remains to be seen whether the new international spec will be a block or stringer pallet and just what size it will be.

Alternative materials—Wooden pallets constitute some 95% of the pallet market today, so they have essentially no room for growth. Plastic, corrugated, and metal pallets have been around for decades and have had a prominent place in material handling shows for years, but they have traditionally been limited to special markets. The demand for alternative material pallets has been growing stronger in recent years, and that trend is likely to continue. Technological advances are making plastic pallets more attractive, but hybrids, such as plastic and wood, may hold the most promise. Plastic pallets typically are used in managed pools or captive environments because they are priced much higher than wood. Plastic pallets have been in use since the 1960s, primarily to ensure sanitation in certain applications. Campbell Soup Company pioneered the use of plastic pallets for shipping raw produce. In the 1990s, however, plastic pallets moved beyond the sanitation niche. The reason: growing recognition of economic and environmental benefits. There also have been significant improvements in materials and manufacturing practices that have lowered prices and made plastic pallets more competitive. They are gaining popularity in the automotive, dry grocery and produce, meat packing, beverage container, and pharmaceuticals industries and as order-picking pallets and captive pallets. Wood will, undoubtedly, lose market share, but slowly.

The environment—An estimated 200 million pallets go into landfill annually. Several companies are utilizing pallet lumber in experimental lumber manufacturing. One such facility manufactures a laminated lumber product from scrap ends that previously may have ended up

at a landfill. Landscape mulch is another of the products that can be made from old pallets. Environmental pressures are sure to intensify, with more emphasis on recycling in order to avoid taking up landfills and cutting down trees.

Pallet management—The 1990s brought about the emergence of pallet management services, with networks of pallet companies providing pallet management functions over wide areas of North America. These services involve both pallet rental and closed loop systems with a variety of programs, including systems customized to fit the needs of a given customer or industry.

Packaging—Many manufacturers are using less packaging today than in the past. Thinner boxes often provide less product protection. This may translate into greater reliance on stronger pallets and better materials handling practices to provide additional product protection.

Health matters—Import restrictions have been placed on lumber because of infestation issues, such as the recent Asian Beetle scare on packaging from China. China responded with a requirement for the heat treatment of solid wood packing materials that are made from US softwoods. The regulation also applies to shipments from Japan. Chinese officials claim that the action is warranted because pinewood nematodes have been found in softwood solid wood packing materials from the US. Phytosanitary regulations are reaching deeper into the wood with concerns over fungi and molds. Drying wood may well become a practice to overcome some of there objections.

Europallets—Since the mid-1950s, the Europallet has been the standard across Europe. Rail authorities developed the specification and policed it for years. Later, the Europallet Pallet Association (EPAL) was established to administer the Europallet program. More recently, European packaging reduction and recycling laws were introduced to tax packaging, including pallets. Packaging that cannot be reused or exchanged is hit especially hard. Because most pallets from North America do not match the European standard, they are subject to the higher tax. Only official Europallets or other approved standards are recognized by users and European governments as commercially reusable. Within the next two years, importers will incur the full cost of taxes for goods shipped on unapproved pallets. Market pressure may force product manufacturers and shippers to demand approved pallets from their suppliers. (EPAL has set up the US Europallet Council [USEPAL] to be responsible for licensing and administering the Europallet in the United States. USEPAL has now developed a US version of the Europallet which is adjusted for wood species and fasteners used in North America. The US standard requires detailed specifications for fasteners, moisture content, species, and dimensions. Currently, there is no licensing body or standard in development for Canada.)

Ammonia Safety

David Binder

History

The ancient Egyptians who worshiped the sun god, Ammon, first discovered ammonia. It was their practice to collect the dung of camels and burn it as fuel. They noticed a sharp, pungent odor when the camel dung burned. They also discovered that a white substance could be recovered from the soot of the fires which they called "sal ammoniac," meaning the salt of Ammon.

Joseph Priestley, an English chemist, first isolated ammonia vapors in 1774, and 11 years later a French chemist, C. L. deBerthollet, decomposed ammonia and identified its composition to be one part nitrogen and three parts hydrogen, or NH3. Michael Faraday liquefied ammonia in 1824 when experimenting with a mixture of silver chloride saturated with ammonia gas. He was able to condense the gas into a liquid, and when he opened the tube where this occurred he found the liquid to boil violently. He was amazed to feel the intense cold where the liquid had boiled off, and thus discovered ammonia refrigeration.

Production

Ammonia is a naturally occurring substance, and decomposing nitrogenous organic matter is a major source of ammonia in the natural state. Ammonia is also produced as a by-product of certain processes, such as the destructive distillation of coal to produce coke gas. The largest source of ammonia is through synthesis. Fritz Haber, a German scientist, developed the first practical method of synthesizing ammonia directly from nitrogen and hydrogen in 1912. An engineer, Carl Bosch, worked out some of the engineering and catalyst problems, and the Haber-Bosch process is still used today to produce anhydrous ammonia. The feedstock utilized today for the process is air for the nitrogen and natural gas for the hydrogen.

Properties

As identified above, anhydrous ammonia is the compound formed by the combination of the two gaseous elements, nitrogen and hydrogen, in the proportion of 1 part nitrogen to 3 parts hydrogen by volume. Since one volume of nitrogen weighs fourteen times as much as one volume of hydrogen, on a weight basis the ratio is fourteen parts of nitrogen to three parts of hydrogen, or about 82% nitrogen and 18% hydrogen.

Liquid anhydrous ammonia is colorless and, at atmospheric temperatures and pressures, ammonia is a colorless gas with a very pungent odor. The odor threshold is generally recognized to be about 5 ppm, which gives it an early self-alarming characteristic. Anhydrous ammonia boils at -28°F (-33°C) at one atmosphere and freezes to a white crystalline mass at -108°F (-78°C). When ammonia boils you will usually see a white "cloud" as the liquid ammonia hits the atmosphere. Another property of ammonia is that it has a high latent heat of vaporization, which means that when the material changes state (or boils) it absorbs a lot of heat, 508.6 Btu/lb. (1,183 kJ/kg) at 70°F (21°C). This was the property discovered by Faraday and why ammonia is such an effective refrigerant.

Liquid ammonia is lighter than water, having a density of 42.57 lbs. per ft3 (681.6 kg/m3) at -28°F (-33°C), weighing 5.15 lbs. per gallon at 60°F (0.608 kg/l at 15°C). As a vapor, ammonia is lighter than air—its relative density is 0.597 compared to air at atmospheric pressure and a temperature of 32°F (0°C). Under the latter conditions, 1 lb. of ammonia vapor occupies a volume of 20.78 ft3 (1 kg = 1.3 m3). At 70°F (21°C) and at atmospheric pressure, 1 lb. of ammonia vapor occupies a volume of 22.5 ft3 (1 kg =1.38 m3). Even though ammonia vapor is lighter than air, under certain release conditions the vapors can exhibit heavier than air characteristics, which is important to be aware of in an emergency response situation.

When heated above its critical temperature of 270.3°F (132.4°C) ammonia exists only as a vapor regardless of the pressure. Between the melting and critical points, liquid ammonia exerts a vapor pressure, which increases with rising temperature. When liquid ammonia is in a closed container, it is in equilibrium with ammonia vapor and the pressure within the container bears a definite relationship to the temperature. The volume amount of ammonia in a container does not affect this pressure-temperature relationship. Table 1 lists some common temperature values and the corresponding ammonia vapor pressures.

Ammonia has a high coefficient of expansion as well as a high volumetric ratio of about 850 to 1. As temperature increases, the liquid will become less dense and thus occupy more space within a container. Because of this property, ammonia containers should never be liquid full. Usually, about a 15% vapor space should be maintained to allow for expansion and prevent a hydrostatic pressure situation on a storage vessel.

Table 1

Temperature (°F)	0	20	40	70	100	130
Vapor Pressure (psig)	15.7	33.5	58.6	114.1	197.2	315.6
Temperature (°C)	-20	-5	5	20	35	55
Vapor Pressure [kPa(g)]	89	254	415	756	1250	2200

Circular of the Bureau of Standards No. 142

Ammonia is a very basic, or alkaline, substance; therefore it should not be mixed with strong acids. It also reacts with chlorine to form a very toxic and explosive gas. The common metals are not affected by dry ammonia. Moist ammonia will not corrode iron or steel, but will react rapidly with copper, brass, zinc, and many alloys, especially those containing copper. Only steel or ductile iron should be used for ammonia containers, valves, fittings, and piping.

Under normal conditions, ammonia is a very stable compound. It takes excessive temperatures (about 840-930°F or 450-500°C) to cause it to dissociate slightly into nitrogen and hydrogen at atmospheric pressure. Ammonia gas burns in a mixture with air within a limited range. The range is usually accepted at being 16-25% by volume of ammonia in air, although some resources have widened this range to 15-28%. Note that this data is for pure, dry ammonia gas; when ammonia is contaminated with moisture and oil, the lower flammable limit will be reduced and extreme caution should be taken with flammability issues, especially in a confined area.

Health Effects and First Aid

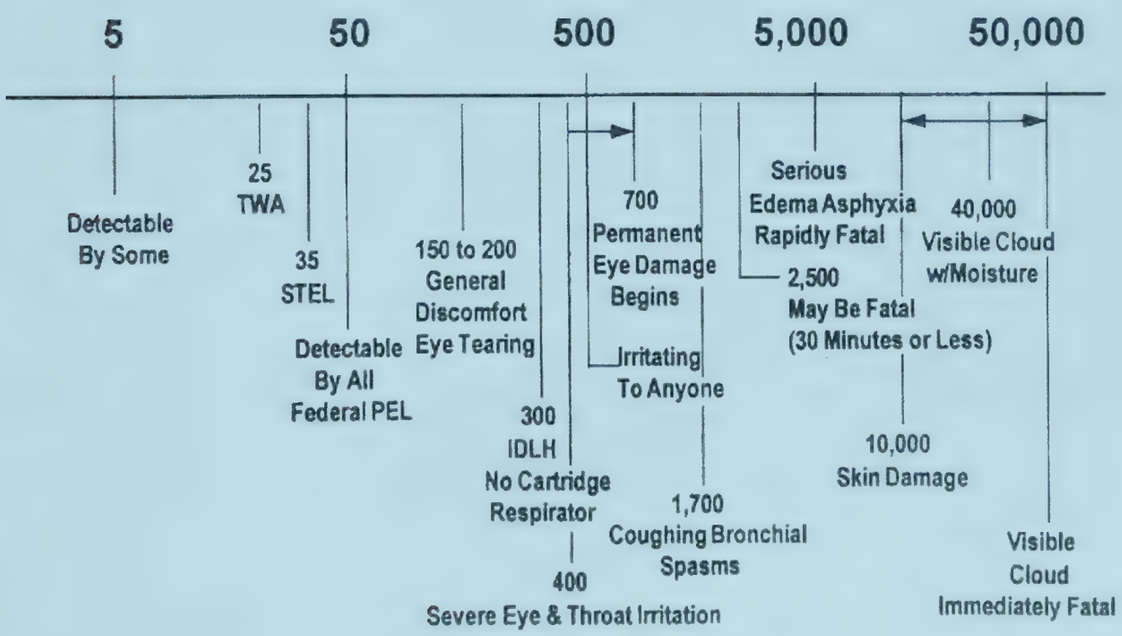
Ammonia is a toxic and corrosive chemical. Acutely, it is irritating and corrosive to skin, eyes, respiratory tract, and mucous membranes. Exposure effects are dose related. Depending on exposure level, it can cause severe burns and eye and lung injuries. Ammonia has a great affinity for water and, since our bodies are mostly water, ammonia will attack our tissues. There are no chronic health effects associated with ammonia exposure and it is not considered a carcinogen.

Skin exposure to liquid ammonia will cause both chemical alkaline burns and frost burns. First aid treatment for skin exposure is to flush the affected area with copious amounts for water for at least 15 minutes. Do not apply topical ointments; use only water. Your eyes are especially vulnerable to ammonia exposure, and anyone working in an area where there is exposure potential must wear full-face chemical goggles (not just safety glasses). Health effects from vapor exposure to ammonia are listed on the graph titled "Rule of Fives." For inhalation exposure treatment, get the victim to fresh air and administer oxygen if necessary.

The US Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) value for ammonia is 50 ppm, which is a time weighted average. Employees would require some type of respiratory protection if working in an environment over the PEL value (usually an air purifying cartridge respirator). NIOSH (National Institute of Occupational Safety and Health) has a Recommended Exposure Limit (REL) of 25 ppm with a Short Term Exposure Limit (STEL) of 35 ppm. Note that some US states have adopted the NIOSH REL as legally binding since state law can be more restrictive than federal law. The Immediately Dangerous to Life and Health (IDLH) value for ammonia is 300 ppm, which requires the use of self-contained breathing apparatus (SCBA) for respiratory protection in environments above this amount.

Ammonia is self-alarming, and olfactory sense is a good method of ammonia detection since the odor threshold is 5 ppm. However the only way to determine an exact ppm concentration is to utilize air sampling monitoring equipment. Your nose will not tell you if you are under or over a PEL environment, and some personnel may not even detect ammonia odor at lower concentrations. To escape an ammonia environment, personnel should be instructed to move laterally and upwind.

Dose/Response



Uses

The main use of ammonia is agricultural—fertilizer. Over 80% of the ammonia produced is utilized in this fashion due to the high nitrogen content of the chemical. Other industrial uses include cogeneration facilities which utilize ammonia to control nitrous oxide (Nox) emissions, water treatment to limit trihalomethane formation after the chlorination process, heat treatment for metals and jewelry, blue print industry in the diazo process, petrochemical, pharmaceutical, chemical processing, pulp, paper, plastics, etc.

Quality

There are two primary grades of ammonia commonly available in the marketplace. There is an Agricultural or Commercial grade of material that must contain minimum water content of at least 2,000 ppm or 0.2% water with a maximum water content of 5,000 ppm or 0.5%. The reason for the minimum water content is to prevent stress corrosion cracking of the metals used in equipment that supplies the agricultural industry.

The anhydrous ammonia grade used industrially, commonly called metallurgical or refrigeration grade, has very little water contamination in it. A metallurgical grade would have a maximum of about 33 ppm water (0.0033 %) and refrigeration grade would have a maximum of about 150 ppm water (0.015 %). For optimum efficiency and effectiveness in your refrigeration system, the ammonia supplied to you for your system should meet or exceed these specifications.

Transportation—Packaging

Ammonia is primarily stored and transported in pressure coded vessels, with the exception of large storage terminals and large barges or ships which store ammonia in a refrigerated system and keep the pressure of the material down to atmospheric conditions.

Be aware that anhydrous ammonia containers with a capacity of less than 165 lbs. (75 kg) (typical ammonia cylinders) are not required to be equipped with overpressure protection devices, such as safety relief valves. Thus these types of containers have the potential to become hydrostatically full due to ammonia's high coefficient of expansion property if exposed to a heat source, such as a fire, and potentially rupture.

Transportation equipment handling bulk shipments and non-bulk shipments (greater than 1,000 lbs. [454 kg] gross weight) are required to have placards on 4 sides of the unit. The following are the types of placards required:

Product	Hazard Class	UN#	Placard
Anhydrous Ammonia US and Puerto Rico	2.2	1005	Non-Flammable Gas
Anhydrous Ammonia Canada	2.2 (8)	1005	Non-Flammable Gas
Anhydrous Ammonia International	2.3 (8)	1005	Poison Gas/Corrosive

Ammonia Refrigeration Systems

Henry B. Bonar II

Basic Information

The US Department of Transportation (DOT) Emergency Response Guidebook can be very useful for ammonia responders. The available information includes the following:

- National Response Center (NRC)—**1-800-424-8802**
- Placards for identification
  - Ammonia—Green Background
  - Hazardous Classification—**2** (Gas)
  - Identification Number (ID No.)—**1005**
- With the ID No., the Guide No. (125) can be looked up in the yellow section of the DOT Guidebook. With Guide No. 125, potential hazards and emergency action information are available.
- With ID No. 1005, the initial isolation and protective action distances can be looked up in the green section. Ammonia 1005 is shown to have a first isolation distance of **100–300 ft. (30-90 m)**.
- Other general information is available, including the definition of Incident Command System (ICS) as defined by the US Occupational Safety and Health Administration (OSHA).
- 50 ppm is bearable.
- 400 ppm is too much to breathe without chemical mask.
- 15,000 ppm is usually a fog and should be avoided.
- When approaching an area suspected of having ammonia, squint your eyes and take short breaths. In critical situations, get as low as possible, since the ammonia is lighter than air. In order to leave an area, and get upwind as soon as possible.

MSDS (Material Safety Data Sheets)

MSDSs provide useful process safety information, including toxicity data, permissible exposure limits, physical data, reactivity (chemical) data, corrosivity data, chemical stability data, and hazardous effects information. Some of the terms and abbreviations used include the following. They are defined by the OSHA and the American Conference of Governmental Industrial Hygienists (ACGIH).

- PEL (OSHA) Permissible Exposure Limits
- TLV (ACGIH) Threshold Limit Value
- STEL (ACGIH) Short Term Exposure Limits (15 minutes)

The primary method of first aid is flushing exposed areas with water for an extended period of time, usually about 15 minutes. If eyes or skin are exposed directly to liquid or concentrated gas, rinse gently with water until direct irritation by ammonia is gone. If eyes are exposed, you may have to hold the eyelids back for rinsing.

The chemical formula for ammonia is NH_3, consisting of nitrogen and hydrogen. Ammonia is not listed or recognized as a carcinogen. Its low boiling point (-28°F or -33°C) will cause freezer burns either by direct or indirect contact of liquid adjacent to such materials as food or plastics. Ammonia will decompose at 1200°F (650°C), permitting ignition of the hydrogen in the presence of oxygen and an iron catalyst. Without the catalyst, it will decompose at 1602°F (872°C), and the hydrogen will burn with oxygen to form water.

Ammonia is considered stable and will not sustain combustion without an auxiliary ignition source, except at high temperatures.

A characteristic of ammonia which has contributed to its safety is its odorous smell. With a relatively high specific volume ratio of 800:1 between its gaseous state and liquid state, a little can be detected quickly. Since its repugnant smell levels are a small fraction of concentrations which can be harmful, it gives early indication of leaks which will need attention.

Ammonia Mask (MSA Model 7-203-1)

The mask consists of five major parts—face piece, exhaust air check valve, flexible canister hose, canister (#448967), and canister straps. The face piece has straps to fit over your head. To put on, put your chin in first while pulling up (not out) on the two side straps. Then tighten until sealed.

Test the seal by disconnecting the hose, placing your hand over the hose connection, and inhaling. If the mask contracts and stays contracted, then it is tight and the check valve is holding. If the mask does not stay contracted, check the straps first. Then if necessary, check the check valve per MSA instructions on maintenance.

After reconnecting the canister, strap it around your waist and tighten the vertical chest straps to hold the canister up so, if necessary, you can look up without the hose becoming taut. The mask is ready to use after you remove the tape on the bottom of the canister. The canister will be good for approximately 12 minutes in high concentrations. When it is exhausted, ammonia will start to pass through. Irritation around the eyes and throat will indicate the canister is being used up and wearer should return to fresh air and replace.

After use with ammonia, the canister should be replaced.

Ammonia Concentration Measurements

Concentrations of ammonia can be measured using the Drager Multi-Gas Detector, Model 21/31. The Drager instrument has six primary parts:

1. Sample holder
2. Check valve
3. Pump
4. Pump counter (on later models)
5. Sample tubes and caps
6. Sample break-off husk

To use the detector:

1. Break off both sample tube ends.
2. Place in holder-hole with sample tube arrow toward pump.
3. Pump slowly 10 times, or instructed number of times.
4. Remove tube from pump, cap both ends, and read (% equals number divided by 10).

Lockout/Tagout Practices and Training

When working on refrigeration equipment operated with electricity, proper lockout or tagouts must be provided. All refrigeration operators and maintenance employees should be familiar with the following:

1. Location of each refrigeration electrical starting or disconnect device.
2. Ability to distinguish exposed live parts from other parts of electrical equipment.
3. Lockout/tagout procedures.
   A. Application of locks and tags, including:
      1. Statement tag.
      2. When to use locks.
   B. Release from lockout or tagout procedures, including:
      1. Inspection of equipment or process.
      2. Check of potentially affected employees.
      3. Removal by employee who applied the device.
      4. Skill to determine the normal voltage of exposed electrical parts.
      5. According to the US Department of Labor Statistics, 120-volt is the most common voltage causing deaths.
      6. A 1000-volt line can jump an air gap of 1 in (25 mm).

Refrigeration Systems

The following diagram shows the primary components in a basic refrigeration system.

The primary components of a refrigeration system are:

- The compressor, where the gas is compressed
- The condenser, where the gas is turned to liquid
- The receiver, where the liquid is stored
- The DX valve, where the liquid is reduced in pressure
- The evaporator, where the liquid is boiled to gas

In a recirculation system, a hand expansion valve, recirculator vessel, ammonia pump, and a hand expansion valve at the air unit replace the function of the DX valve and add a high degree of reliability to a system by virtually eliminating the possibility of liquid floodback to compressors. The recirculator (accumulator) separates the liquid from gas.

Ammonia pumps will normally provide 30-50 psig or 200-350 kPa(g) (more than suction pressure) to the liquid going to the evaporators (air units).

Useful Ammonia Information

Ammonia is a very stable compound consisting of the elements nitrogen and hydrogen with the chemical formula of NH_3. Ammonia has several similar characteristics of water, which has the formula of H_2O. Nitrogen and oxygen are next to each other on the Periodic Table of Chemical Elements. Oxygen has an atomic weight of 16 and nitrogen 14. This similarity contributes to why ammonia and water, with similar hydrogen bonds, are so miscible in each other in liquid form.

In earth's atmospheric air pressure of 14.7 psig (101.4 kPa(g)) at sea level, ammonia boils at

-28°F (-33°C) and water boils at 212°F (100°C). To keep ammonia from boiling at temperatures higher than -28°F (-33°C), it must be kept in a closed piping system under pressure for use in the refrigeration cycle.

Ammonia makes a good refrigerant on earth because its boiling point, while below the freezing point of water (the main ingredient of perishable foods), is at or near atmospheric pressure during the majority of the time it is in use in a refrigeration system and most exposed to the process and the people associated with the process. The similar ammonia pressure (on the low side of the cycle) in air units etc. means leaks would normally be small because the driving pressures. or pressure differentials, are low.

When used as a refrigerant, ammonia is alternately boiled (evaporated) to a gas and condensed to a liquid. Ammonia is very effective as a refrigerant. with a high heat of vaporization (the heat it will absorb while boiling). With a latent heat of 500 Btu/lb (1160 kJ/kg), ammonia can absorb a lot of heat. such as is required during a freezing operation. When it converts from liquid to gas it expands in volume approximately 800:1.

Another reason ammonia has widespread use as a refrigerant is that the pressure at which it will condense back to a liquid is relatively low compared to other common refrigerants. At 151.7 psig (1050 kPa). it will turn back to liquid at 85°F (24°C). Piping systems and equipment can be designed with housing strengths in the range of 250-400 psig (1700-2700 kPa(g)).

Ammonia is a well known refrigerant in large scale industrial refrigeration plants. It has been used as a refrigerant for more than 120 years. but until now it has not been used widely in small refrigeration plants. We find that small refrigeration plants use ammonia as an alternative refrigerant. Small ammonia plants can be manufactured and used in practice without significant problems and, in some cases, even with energy savings.

Industrial and Cold Store Refrigeration

Users in the industrial and cold store refrigeration sector include chemical, pharmaceutical, oil, and gas companies. Ammonia had been the refrigerant of choice in this sector for many years before CFC restrictions came into force. The vast majority of US cold stores and over two thirds in Germany use ammonia. The technical feasibility and commercial availability of ammonia is well demonstrated. Almost all of Nestle's systems worldwide are now running on ammonia. Unilever has made a complete switch to ammonia. as has Ciba Geigy in Switzerland. Recent tests convinced Sainsbury to install as ammonia-based secondary cooling system in a new superstore in Horsham. Sussex. even though just eighteen months earlier the company stated, "it is madness to suggest that a modern supermarket might equip with ammonia."

Using ammonia has many advantages compared to the use of HCFCs and HFCs:

- More than 120 years of practical experience
- Excellent thermodynamic and thermophysical properties at required temperatures
- Higher energy efficiency in most temperature ranges
- Well known oil tolerance
- Great tolerance to water contamination
- Simple and immediate leak detection
- Lower refrigerant cost
- Smaller pipe dimensions leading to lower plant investments
- Not miscible with most known oils

Despite all the advantages of using ammonia, there are some disadvantages, also:

- Toxic at low concentrations in air
- No tolerance to some materials (e.g., copper)
- High discharge temperatures

Recirculator (Accumulator)

The recirculator (also called a slop or suction trap or low pressure receiver) provides several functions in a refrigeration system:

- Separation of liquid and gas.
- A means to remove or transfer excess liquid.
- A means to detect and stop excess liquid before it gets to compressors.
- A place to eliminate "flash" gas (before it gets to air units).
- A place to drain oil.
- A place to store liquid refrigerant.

The way gas and liquid are separated is to size the cross section area of the recirculator large enough to slow down the gas velocity to about 100-150 ft/min (0.5-0.75 m/sec) so the spray and droplets will fall down and the gas can be directed up. Vertical tanks are **much more** reliable than the horizontal type because their cross section area will not be reduced by liquid filling the tank during adverse conditions.

Ammonia pump suction lines should be configured and sized so they do not need additional vent lines near the pump. The recirculators are equipped with control columns with a series of float switches which provide the electrical controls with the following control functions:

- High level switches will shut off all compressors.
- An alarm level, usually about 12 in (300 mm) below high level, is sometimes used for transferring excess liquid to another vessel by opening a solenoid valve on a transfer line from its ammonia pumps.
- Level switches between alarm and low are used for controlling liquid levels.
- Low level switches will turn off ammonia pumps.

Compressor Type

The most common type of compressors include:

- Reciprocating (positive displacement)
  A. Multicylinder (high speed – ~1200-1800 rpm)
  B. VSA (vertical single acting [slow speed] <500 rpm)
- Rotary screw (1800-3600 rpm, and sometimes higher)
- Mono screw (star type)
- Rotary vane (slotted rotary)

Reciprocating compressors, also referred to as positive displacement compressors (pistons sealed with rings), move gas by the motion of the pistons up and down, as suction and discharge valves open and close, permitting gas to enter or leave the cavity created by the motion of the piston. Compression ratios of higher speed compressors are generally in the range of 8:1, whereas slow speed compressors can be in the range of **11:1**.

Screw compressors create cavities by the meshing of rotating "male" and "female" gears, with

movement of the cavity from one end of the rotors to the other, closing the cavity as it reaches the discharge port. The action of the gears permits compression without the use of suction or discharge valves. Compression ratios in the range of **20.1** are achievable.

Mono screws are similar to rotary screws in that a displacement cavity is created between a gear and a perpendicular intermeshing "star" gear to create a moving cavity from inlet to discharge. The compression occurs without the use of suction and discharge valves, although practical compression ratios are generally considered less than rotary screw type compressors.

Rotary vane compressors create a displacement cavity by rotation of a cylindrical slotted rotor placed eccentrically in a barrel or housing which, by the motion of the blades, radially, in and out, create a change in the displacement cavity as the rotor turns.

Compressor Efficiency

Compressor types vary in efficiency (BHP/TR or kW/kWR). Large bore, slow speed, piston (positive displacement) compressors are the most efficient. As the bore goes down and the speed goes up the piston machine efficiency goes down. A 3-4 in. (75-100 mm) bore piston compressor, however, operating at 1200 rpm will typically be 10–12% more efficient than a screw, "star," or rotary-vane type machines. Rotary screw compressors with ball (or roller) bearing supported rotor will, in time (after wear), be more efficient than **journal shaft bearing** supported rotary type screw. Efficiencies of screws with some wear have been observed to be 36% less than a comparable piston compressor. Accumulative effects of tolerances and wear, if left unabated, can permit clearances of over 0.030 in. (0.762 mm) between rotors and the barrel of screw compressors.

If economizing side ports are present in screw compressors, efficiency goes down as well (less compression will be done), although this can be offset a little if the system is low temperature, single-stage, **and** liquid subcooling can be provided (where otherwise it would not be provided). If subcooling can be provided by other compressors (without the use of side ports), the system efficiency will be improved. There is a general misconception that the use of side ports or economizing greatly improves efficiency. If liquid subcooling can improve system efficiency 15–16%, subcooling with a side port may only be able to deliver 50-60% of what is achievable by providing liquid subcooling directly by other high stage compressors (not the side port).

Generally, piston compressors are limited to the high range of 600 ft^3/min. (283 L/sec) or approximately 250-300 hp (150-220 kW). Screw compressors are available in larger sizes approaching the range of 8.000 ft^3/min. (3,775 L/sec). Because of the oil system and complexities of unloading a variable VI (compression ratio) slide valve mechanism on screw compressors, it is generally more desirable to use them as **base** machines running them fully loaded without cycling. Piston machines, on the other hand, have far simpler oiling systems and tend to be more reliable when cycled and are effective load matching machines. Although individual pistons could be unloaded, they also, if possible, are best run fully loaded and turned on or off as needed.

Compressor Uses and Operation

Compressors are used in several ways in a refrigeration system. These are generally as follows:

1. Single stage (From evaporator low pressure to condensing pressure.)
2. Booster (compressor)—Also called **low side** and **first stage**. (From evaporator to an intermediate pressure. The intermediate pressure may also be the pressure of other [high temperature] evaporators.)

3. Compressors—Also called **high side** and **second stage**. (From intermediate pressure to condensing pressure. Usually for higher temperature evaporator loads.)

Other than normal mechanical wear, the primary concern in operating compressors in refrigeration is liquid refrigerant floodbacks passing to the compressors from the suction lines. If oil is foaming excessively, check to see if refrigerant is getting into crankcase or oil separator.

Sudden reductions (15–20 psig or 100-135 kPa) in suction pressure, or sometimes only slight reductions (3–5 psig or 20-35 kPa), can cause boiling activity in the evaporators to become so rapid that the newly produced gas (800:1 ratio in volume) can cause excess gas velocity which will act as a geyser and **carry liquid** at high rates of speed through the return pipeline system. These high speeds and excess quantity of liquid can then exceed separation velocity of accumulator and recirculator tanks and vessels. Large quantities of liquid can then enter compressors and damage or cause major breakage, particularly for reciprocating compressors.

Screw compressors sometimes use **thermosyphon** oil coolers which return ammonia gas (and sometimes liquid) back to the condensers or receivers. The hot oil in oil coolers will make flashing or geysering of liquid ammonia occur if discharge pressures are suddenly dropped (usually 15-25 psig or 100-170 kPa). If a compressor or its motor bolts are loose, the alignment should be checked after tightening.

Oil with Ammonia

Compressors all require lubrication for moving mechanical parts and bearings. Screw and "star" compressors also use oil for sealing clearances and for internal cooling and absorption of heat of compression. Oil used for these purposes will carry over with the refrigerant gases and needs to be separated and returned to the compressors. This is generally done with coalescent oil separators, which use impingement filters to help oil droplets form and separate by gravity. Floats or oil pumps return oil to use for lubricating the compressor. Oil has a higher specific gravity than ammonia and will go to the bottom if it is mixed with liquid ammonia. Because the oil will not stay mixed, it can be separated and drained routinely from low points in the system. When the ammonia is very warm, like during compression, oil will tend to mist and become "atomized" and is more difficult to separate.

Draining oil is one of the most hazardous operations in an ammonia system. Special care needs to be taken, particularly if it is done with a flexible hose. Standard operating procedures need to describe the safety equipment and tools needed for oil draining. If, during oil draining, the oil is permitted to spray out in a mist, fire may be a hazard where arcs or sparks may be present.

If **oil pressure failure** occurs on a compressor, care should be taken to not restart the compressor too often without knowing what caused the shutdown (i.e., resetting oil pressure failure switch on reciprocating machine permits bearing to run without lubrication). Testing oil regularly may also help to detect unusual wear (by measuring how much metal is present). Oil can be tested and filtered and reused. Care needs to be taken in keeping oil compatible with what oil is in the system. Careful checks should be made before changing the type of oil used in a system. Automatic fill pumps' piping systems can help to minimize oil loss and spills on floor.

If **hot gas** defrost systems are used in air units, oil passed to the evaporators, or low side, can be automatically returned to vessels or recirculators where it can be drained either automatically to a still, or manually.

High temperatures from excess discharge temperatures or worn parts can cause darkening of oil. Very dark oil may be caused by very high oil temperatures and oxygen or air entering the system.

Condensers

Condensers are very often overtreated or mistreated. Any acid based treatment used to keep solids suspended makes all the metal of the condenser and surrounding area susceptible to rapid corrosion. We recommend no **acid** treatment. At the most, periodic cleaning with manufacturer's recommendations.

A healthy bleed off (1/6) feed rate is recommended, and periodic mechanical cleaning by expansion and contraction of the scale is the safest way to prevent corrosion.

Hardness (calcium and phosphates) deposits form at about 120°F (49°C) and above, system discharge below this level will have little scale form. This is particularly true of systems using all screw compressors, or ones using desuperheaters for heating water.

If condenser pressure goes too high during a startup, the evaporator load should be slowed down by turning some evaporators off, until the compressors (or boosters) and condensers can catch up and the excess momentary load subsides.

When outside temperatures reach 32°F (0°C), water pumps should be shut off and pans, pumps, and outside lines drained.

Use of relief valves on condensers **should** be avoided. It would be **very** difficult to "trap" a condenser full of liquid. Exposure of the relief valve to weather and breakage and relieving in the presence of someone is very high. SOP's can be used to describe the proper way to close a condenser coil. There is far less health and safety risk to personnel by letting leaks, if they occur, be in the tube bundle where they are bathed in water.

Air Units

Air units are the most common equipment used for evaporator cooling of space (air) and perishable food products. This generally occurs by the boiling of liquid inside coil tubes while passing air over them on the outside of the tubes.

Air units vary in type depending on their physical placement which can be **roof** mounted, ceiling mounted inside, or **floor** mounted. They are generally manufactured with three different types of fan sections which include centrifugal, axial blade, and multiple propeller type.

Generally, **axial** fan units are used for blast freezers, while centrifugal fan units are used for large room, "long air throw," applications. Propeller units tend to be smaller, requiring more units in rooms with low ceilings and limited means of structurally supporting larger air units. Normally, rooms would have at least two air units. More than three units and more than three motors tend to increase maintenance costs proportionally.

The most efficient type of fan for air units is large "squirrel cage" centrifugal units with pony motors, permitting low speed fan operation except during peak periods of load. If voice communication in a room is important, centrifugal units are generally preferred over axial. Roof

mounted air units tend to be the preferred method of cooling air. Primarily, this is because suction lines can be sloped without "trapping" at each air unit. Trapping can create irregular flows and additional pressure drops in lifting recirculated liquid up a suction line. The refrigerant pressure inside coils of the air units is maintained by removal of gas by the compressor. Flow of liquid to air units is controlled by (hand) expansion valves, permitting pressure to reduce to boiling points (corresponding to the pressure being maintained by the compressors). Unless the air unit is equipped with a back pressure regulator, the boiling temperature of the liquid, as it evaporates, will follow its saturated curve or temperature relationship for that refrigerant. As the pressure moves up or down, its evaporation temperature moves up or down correspondingly. The relationships of temperatures to its corresponding boiling pressure is described with saturated temperature charts available through the Bureau of Standards on any fluid used as a refrigerant. Each refrigerant will have its own temperature/pressure relationship.

Piping Systems

Block diagrams help to show relative location of equipment and piping arrangement. Actual piping drawings are needed to show complete piping details.

All **suction lines** should **slope** and only "trap," if necessary, at each evaporator. All hot gas lines should come from the condenser or receiver and slope back to the condenser or receiver. If traps are necessary in the hot gas line, inverted floats should be installed to remove liquid.

If servicing of a portion of the piping system is in an area of limited **ventilation**, portable fans should be used to bathe the area with fresh air.

In properly designed piping systems, there would normally be two reasons for **liquid refrigerant carryover** to compressors:

A. A surge in load caused by:
   1. Evaporator loads being turned on too fast.
   2. Lowering compressor suction pressure too rapidly.
B. A liquid solenoid not closing, and a liquid transfer not occurring, and a high level float switch not operating.

If **glycol** concentration of a glycol/water solution becomes too low, freezing of water can occur. While pumping fluids, if water or glycol pumps **surge**, the pumps may be drawing in air or cavitating.

Especially after a refrigeration system has been opened to air (oxygen), moisture can combine with oil and oil residue, and cause **strainers** to clog. It may be safer to remove a strainer permanently. Low temperature liquid solenoid strainers, which are not clogging with solid debris, **can be removed** so oil coagulants can pass through valves on to drain points in the system. If stoppage of a valve occurs, it would be safer to remove the valve than bleed down a clogged strainer which may have liquid ammonia trapped inside. Personnel exposure can be minimized if coagulants can be passed to a more suitable draining point. Generally, **servicing** a **solenoid** valve, particularly for air units, is much less risk to personnel (from liquid ammonia) than **servicing** a **strainer** filled with frozen coagulants.

Refrigeration Valve Information

Thermal expansion valves require, at least, annual maintenance because of wear of their ori-

fices by wire drawing. Their adjustments are very sensitive for maintaining proper superheat, for assuring total boiling and no liquid returning in suction lines.

Pressure regulators are usually one of three types:

A. Those that maintain a **back pressure** (upstream side), sometimes for two different pressures, or dual purpose, and also as a stop valve.
B. Those that maintain **outlet pressure**.
C. Those that maintain a **differential** pressure.

Very positive shutoff **check valves** should be used on all compressor discharges in a **horizontal** position. Teflon seats are the most reliable.

The **dual manifold** on **relief** valves should be in one position or the other, not half way, which would activate both relief valves.

Solenoid valves are electrically operated shutoff valves normally using 120 volts to operate. These types of valves can be used for liquid lines, as well as hot gas lines.

Gas powered **suction stop valves** are usually used for suction line stop valves, such as for defrost functions. The spring return piston solenoid hot gas **and** solenoid vent type (Refrigerating Specialties valve number S9A) is far more reliable than the single solenoid gas powered type (Refrigerating Specialties valve number CK-2).

System Training

The following points will help a starting refrigeration employee become proficient with a system which is new to him or her.

A. First realize you will never remember or know everything about a system.
B. Know whom you can talk to and where the information you need is located.
C. Carefully study the pipelines.
D. Carefully study the valve positions.
E. Watch the action of the solenoid valves.
F. Watch liquid levels change.
G. Watch the system pressures go up and down.
H. Watch what compressors are turned on and off under what load conditions.
I. Study the defrost sequence of air units.
J. Study the staging of air unit defrost.
K. Study room temperature logs.
L. Study and watch how refrigeration evaporators are turned on after a shutdown.
M. Study how compressors are turned on after a shutdown.
N. Learn which loads are sensitive in causing liquid floodback when started or turned on during a startup.

Equipment Mechanical Integrity Inspection Training

Several methods are used for inspecting refrigeration equipment. Most all of these would be nondestructive methods of inspection. These methods include the following:

I. Visual inspection
  a. Unusual vibration
  b. Event sense
    1. Unusual operating modes (on or off)
    2. Unusual cycling
  c. Excessive oil or grease residue
  d. Excessive belt wear or residue
  e. Sight glass inspection
    1. Liquid levels
    2. Oil levels
    3. Oil conditions
      - Foaming of refrigerant
      - Discoloration
  f. Mechanical float switch position
  g. Valve or pipe sweating or icing
  h. Moisture/vapor (fog)
    1. Evaporative condenser plumes
    2. Defrost "fog"
    3. Relief vent line plumes
  i. Intermittent pipe movement
  j. Equipment/surface discoloration, paint, or rust
  k. Water levels and flows
    1. Condensate drains
    2. Condenser bleed off
    3. Seal cooling fluids
    4. Jacket cooling fluids
    5. Fluid reservoir levels
  l. Instrument reading
    1. Pressure gauges
      - System pressure
      - Equipment gauges
      - Temperature indicators
      - Micro-processor transducer readings
    2. Log sheet data
  m. Oil drain foam consistency
  n. Air unit frosting
  o. Time of day influences
    1. Production activities
    2. Freezing activities
  p. Evidence of smoke
    1. In air
    2. On electrical boxes and/or conduit
    3. Motor housing
    4. Solenoid coil enclosures

II. Smell (nasal, odoriferous)
  a. Ammonia
    1. Air ventilation outlets
    2. Seal proximity
    3. Valve proximity
  b. Electrical
    1. Motor burnout
    2. Electrical wire and junction boxes
    3. Computer process board
    4. Solenoid valve coils

III. Touch/feel
  a. Pipe temperatures
    1. Condenser inlets/outlets
    2. Liquid lines
    3. Compressor jacket piping
  b. Equipment temperatures
    1. Motor housing
    2. Bearing proximity
    3. Solenoid coils
    4. Electrical conduits
    5. Compressor booster head and cylinder walls

IV. Sound or hearing
  a. Equipment
    1. Belt vibration or squealing
    2. Bearing vibrations
    3. Sound of liquid floodbacks into compressors
    4. Bearing rattle
    5. Metallic rubbing in compressors
    6. Sound of broken valve plates
    7. Pump cavitating
  b. Piping
    1. Liquid hammers
    2. Relief valve opening
    3. Liquid flow sounds
      - Hand expansion valves
      - Back pressure regulator stop valves

Although these are used for inspection and mechanical integrity of equipment and piping systems, the employees would use them daily during normal operation.

General Information (Definitions)

1. A Btu (British thermal unit) is the heat to raise one pound of water one degree F. A kcal (kilocalorie) is the amount of heat to raise one kilogram of water on degree C.

2. Superheat is the heat added to a gas just after it has changed from a liquid to gas.

3. Subcooled is the heat removed from liquid just after it has turned from gas to liquid.

4. Absolute pressure is the air pressure caused by the gravitational effect on air at a planet's surface (for earth at sea level, 14.7 psig or 101.4 kPa(abs)).

5. Compression ratio is the absolute outlet pressure divided by inlet absolute pressure.

6. Shell and tube heat exchangers would generally have ammonia outside the tube and another fluid inside the tubes.

7. TR (tons of refrigeration) is the rate of Btu removal that would freeze one ton of water in 24 hours (or the rate of removal of 12,000 Btu/hour). One TR equals 3.5172 kWR.

8. Solenoid valves are electrically operated automatic stop valves (usually 120-volt).

9. DX Valve is a valve used to let liquid refrigerant expand (flash) to a lower pressure. The liquid would normally pass from a higher pressure, slightly subcooled, to a lower pressure where a portion would flash to gas and the remainder be liquid at the saturated temperature of the lower pressure.

Self Test

Instructions: See how many of the questions you can answer from memory. Then refer back to the test to research the other answers and check your work.

DOT Emergency Response Guidebook

1. Emergency Response number is _____.

2. What color is DOT's Ammonia Identification Placard? _____

3. Ammonia's ID No. is _____.

4. The response Guide No. for ammonia is _____.

5. The Guide Number is used to get information on what two items?

   _____ _____

6. What is the First Isolation Distance for ammonia? _____

7. The OSHA term, ICS, means _____.

8. To escape through or from an area, one can squint one's eyes as closed as possible and

take what kind of breaths?

_____

9. Ammonia gas is _____ than air.

10. One should try to stay _____ of ammonia gas.

MSDS (Material Safety Data Sheets)

1. What OSHA regulation requires MSDSs? _____

2. What do the following acronyms mean?

   PEL _____

   TLV _____

   STEL _____

3. If skin is exposed to concentrated ammonia, rinse for 15 min with _____.

4. At what temperature can ammonia be decomposed? _____

5. The chemical formula of ammonia is_____.

6. The two elements in ammonia are _____ and _____.

Ammonia Mask (MSA Model 7-203-1)

1. After using a mask in an emergency, the canister can be reused. T F

2. A canister should be used if it is out of date. T F

3. The vertical chest straps on an industrial mask can be used to keep the weight of the chemical canister off the flexible hose. T F

4. The waist strap should be snapped around the waist to keep canister in close. T F

5. Do not remove the tape on the bottom of the canister when it is in use. T F

6. To test mask for tightness, unscrew hose and hold hand over inlet and inhale. If mask stays collapsed to face, the readjustments are proper. T F

7. The five major parts of a mask are:

1. _____ 2. _____

3. _____ 4. _____

5. _____

8. How long can you use a mask canister in high concentrations? _____

Ammonia Concentration Measurement

Name the six parts, or items, used with detector.

1. _____ 2. _____

3. _____ 4. _____

5. _____ 6. _____

To use the detector, which of the following should you do?

1. Break ends of sample tube. T F

2. Insert with arrow to pump. T F

3. Pump number of times on instructions. T F

Lockout Information

1. Name some refrigeration equipment that needs to be locked or tagged out during maintenance.

   1. _____ 2. _____

   3. _____ 4. _____

2. Removal of lockouts or tags should be by the person who _____.

3. Do you know where to get lockouts or tagouts? _____

4. What voltage causes the most deaths? _____

5. How far can 1000 volts jump if you are grounded? _____

Refrigeration Systems

1. The primary components of a refrigeration system are:

   1. _____ 2. _____

   3. _____ 4. _____

   5. _____

2. A recirculation system is different than a DX system because it feeds more liquid to the evaporators than will be boiled into a gas. What happens to excess recirculated liquid returning in a suction line? _____

3. In what components is the pressure normally the highest?

   1. _____ 2. _____

   3. _____

4. Where is the pressure the lowest? _____

5. How much pressure (above its suction pressure) will ammonia pumps apply to liquid it pushes through the piping system? _____

Ammonia

1. Ammonia is similar to what other common liquid? _____
2. What is the boiling temperature of ammonia at atmospheric pressure (psig)? _____
3. What is the volume ratio of ammonia gas to liquid? _____
4. If ammonia gas is compressed to 151.7 psig and permitted to cool, at what temperature will it start turning to liquid? _____
5. Ammonia is an effective refrigerant because it has a high _____ of about _____ BTUs.

Recirculator (Accumulator)

1. List three functions of recirculators.

   1. _____

   2. _____

   3. _____

2. Recirculators are equipped with _____ columns.
3. Name three things float switches do:

   1. _____

   2. _____

   3. _____

4. Which type gas/liquid separator vessel (horizontal or vertical) is more reliable?

   _____

Compressor Type

1. Name the four common types of ammonia compressors:

   1. _____ 2. _____

   3. _____ 4. _____

2. What is another name for reciprocating compressors? _____

3. Name the approximate compression ratios for these types of compressors:

   Slow Speed Reciprocating _____

   Rotary Screws _____

Compressor Efficiency

1. What type of compressor is the most efficient? _____
2. What type of bearing makes screw compressors most efficient? _____
3. "Economizers" are only efficient if they provide subcooling of _____.
4. Side port (economizing) subcooling of liquid refrigerant is the most efficient means of subcooling liquid. T F
5. What type of compressor is best for cycling to match load? _____
6. For efficiency, after starting, run screw compressors fully _____.

Compressor Uses and Operations

1. Sudden drops in suction pressures can cause liquid _____.
2. In starting a system where liquid in suction lines may be expected, you may want to start an unloaded (small) screw compressors in lieu of what type? _____
3. Sudden reductions in discharge pressure may cause thermosyphon oil coolers to _____ off.
4. If thermosyphon coolers cannot recover and start getting liquid ammonia quickly, the screw compressors may go off on high _____.
5. If foaming is observed in the oil, one should check and see if _____ is getting into the crankcase or oil separator.

Oil (with Ammonia)

1. Oil is heavier than ammonia T F

2. Testing oil can be helpful in checking wear on a compressor. T F
3. Oil draining operations should be hard piped (in lieu of hoses). T F
4. Hot gas defrost can return oil to vessels and drain points. T F
5. Oil is used to help seal clearances in screw compressors. T F
6. Oil is used to help cool screw compressors. T F
7. Coalescent filters can be used to help separate oil in compressor discharge. T F
8. Discolored (dark) oil may indicate high oil temperature during operation. T F

The components or parts of an oil system are:

1. Oil strainer T F
2. Pressure regulator T F
3. Oil pump T F
4. Oil cooling systems T F
5. Oil separators or reservoir T F

Condensers

1. Continuous acid treatment should be avoided. T F
2. 1/6 bleed off should be used to hold down water solid levels. T F
3. Scale forms at above 120°F (48.9°C). T F
4. Mechanical cleaning by operating the condenser dry momentarily in the winter, then turning on the water, causes the scale to flake off. T F
5. Bleed water rates should be checked frequently. T F
6. Spray nozzles should be checked frequently. T F
7. Fan belts should be checked frequently. T F
8. The condenser is not working If the inlet is as cool as the outlet. T F
9. Water pumps should be drained below 32°F (0°C). outside air. T F
10. Installing relief valves on condensers should be avoided. T F

Air Units

1. What throttles liquid entering the air unit coil? _____
2. What removes refrigerant gas from air units? _____
3. The "boiling temperature" relationship of liquid/gas is called _____.
4. Name three types of fans used on air units.
   1. _____
   2. _____
   3. _____

Piping Systems

1. If glycol concentration gets too low, the water (solution) could freeze. T F
2. It may be safer to remove the strainer basket from the solenoid strainer so that bleed down can be made by loosening solenoid flanges rather than removing the bottom cap of the strainer. T F
3. Block diagrams show everything you need to know about a system. T F
4. A portable fan can be very helpful in repairing valves. T F

Valve Information

1. Automatic thermal expansion valves should be serviced at least once a year. T F
2. Pressure regulators are usually one of three types. T F
3. Very positive compressor discharge check valves are needed to keep regrigerant out of the oil separator. T F
4. Dual manifold valves should be set in the middle so both reliefs will be active. T F

System Training

1. Name seven things to study to become familiar with a refrigeration system.
   1. _____
   2. _____
   3. _____
   4. _____

5. _____

6. _____

7. _____

2. Discuss any situation which may have potential hazard with the person who may know the most about it. T F

Equipment Mechanical Integrity Training

1. Name three items you could check with visual inspection.

   1. _____

   2. _____

   3. _____

2. Name three items you could check with smell inspection.

   1. _____

   2. _____

   3. _____

3. Name three items you could check with touch inspection.

   1. _____

   2. _____

   3. _____

4. Name three items you could check with hearing inspection.

   1. _____

   2. _____

   3. _____

Understanding Energy Use

Gerard N. Von Dohlen

Basics of Electricity

Public refrigerated warehouses buy electricity to power the refrigeration system, lights, battery chargers, and more. That electricity is sold in kilowatt hours, so, needless to say, it is useful to understand what a kilowatt is. A kilowatt is 1000 watts, and a watt is one ampere times one volt. Although that is the technical definition, it doesn't give one very much insight to what it means. Most people understand horsepower (HP). Your car has an engine probably capable of producing around 200 HP, which is the equivalent of a 149 kilowatt engine. Those who use the metric system usually measure engines in kilowatts. A 1-HP motor is the equivalent of about 3/4- kilowatt. One HP equals 0.745 kilowatts or a kilowatt is 1.34 HP.

People use small electric resistance heaters in their office or homes. Those heaters are typically around 1500 watts or 1.5 kilowatts. If a person operates that heater for one hour, the heater would use 1.5 kilowatts for one hour or 1.5 kilowatt hours (kWh). That is how electric consumption is measured. If a kilowatt hour costs 8 cents in your area, using that little electric heater cost about 12 cents per hour (1.5 kWh x 8 cents/hour).

Assume for the moment that one has a 150-ton compressor and that compressor is being driven by a 300-HP motor. That 300-HP motor is about 224 kilowatts (0.745 kilowatts per HP). The motor would probably be about 92% efficient. Divide that 224 by 0.92 and that motor is consuming about 243 kilowatts while it is in use. If that motor is in use for one hour it will obviously consume 243 kilowatt hours. Thus at 8 cents per kilowatt hour the compressor cost is $19.44 (243 kW x 1 hour x $.08 per kWh) to operate for one hour.

Power can be measured in heat content; in fact, it is often the easiest way to think about power. For instance, one kilowatt is equivalent to 3413 BTUs per hour. Therefore, if an evaporator, for instance, had a 3/4-horsepower motor in it (equivalent to 0.56 kilowatt motor) with 80% efficiency, that motor would use about 0.70 kilowatts of electricity. The motor is inside the refrigerated space. Therefore, that energy (0.70 kilowatts) is entering the room and the refrigeration system must take it out or the temperature will increase. If that motor is operating for one hour, then 0.70 kilowatts (2389 BTUs = 0.7 x 3413 BTUs) will enter that space. Two thousand three hundred eighty nine (2389) BTUs is 0.20-ton (one ton equals 12,000 BTUs per hour). So a 3/4-horsepower motor will require 0.20 tons of refrigeration just to remove the heat from the electricity powering the motor.

Electric lights cause the same problem. Assume that a 400-watt metal halide fixture is in a warehouse. That 400-watt fixture is drawing 0.4 kilowatts. Therefore, it is putting 0.4 times 3413 or 1365 BTUs in that space. One ton has 12,000 BTUs so that light fixture is putting out about 0.11 or 11% of one ton. So if a refrigerated space had 40 such fixtures, 4.55 tons of refrigeration are required to take the heat out of the room that is put in by the light fixtures.

Demand

Assume that one is operating a warehouse with a 300-HP motor driving a 150-ton compressor operating in the middle of the summer, with a second identical backup or peaking compressor available if needed. The motor driving the compressor will, as described above, draw about 243 kilowatts. Generally a refrigerated warehouse compressor room will draw about 60% of the total power. Therefore, this warehouse drawing 243 kilowatts will have a total kilowatt usage of around 405 kilowatts. The weather starts to get warmer at 10 to 11 AM, and the refrigeration systems will try to maintain a 0°F (-18°C) temperature. The temperature rises because of the heat and humidity outside, and the system turns on the additional compressor. The demand, which is a relatively instantaneous measurement of power usage, will go from 405 kilowatts to 648 kilowatts (405 kW + 243 kW).

In a high demand period, public utilities charge about $9.00 per kilowatt for demand. The demand charge for the month would be based therefore on this peak of 648 kilowatts, which at $9.00 per kilowatt is a demand charge of $5,832. If that compressor operates for one 15-minute interval in most regulated jurisdictions, demand charges will increase to 648 kilowatts and the demand bill for the entire month would be $5,832. One 15-minute interval is increasing the electric bill by $2,187 (243 kilowatts x $9.00 per kilowatt). The situation is actually a little worse. When an electric motor starts, an initial very high flow of amperage or current takes place usually two to four times the operating level. So for a short period as the motor comes up to speed, the motor will draw as much as four times normal power. Averaged over a 15-minute interval, it will produce an added demand charge in excess of 243 kilowatts. Needless to say, turning compressors on in the middle of peak power periods is expensive.

Let's continue this simple example to see in perspective how large this demand is. Assume that during the month the warehouse continues to operate at about 405 kilowatts, 24 hours a day, 31 days per month. The total consumption of kilowatt hours will be 301,320 (405 kilowatts per hour x 24 hours x 31 days). The usage charge for this hypothetical bill would probably be about 6 cents per kilowatt, which would be about $18,079 (301,320 x 6 cents). Demand charge calculated earlier was $5,832. The total bill therefore would be $23,911, of which $5,832 is demand. The demand charge would be about 25% of the bill, which is reasonable for a public refrigerated warehouse. If the demand charge in the off peak hours (at night) was $1.00 per kilowatt (which is reasonable) and if the 243 kilowatt compressor had been turned on at night instead of the daytime, $8.00 per kilowatt demand for 243 kilowatts or $1,944 would have been saved. That is a classic case of demand shifting. If that had been done the temperature in the room would have risen above 0°F (-18°C) because the additional compressor was not turned on in the daytime. When the compressor was turned on at night, the temperature was driven below 0°F (-18°C) so that the 24 hour average would have been 0°F (-18°C), but the company would have saved approximately $2,000 on a $23,000 bill or almost 9%.

In deregulated markets, as discussed in the next chapter, electric prices vary astronomically, primarily because of air conditioning loads. When a large city such as New York City gets hot and humid, the air conditioners maintaining temperatures in offices, apartment buildings, and hotels draw more and more power. The region may not have that much power available, so it will start to draw power from other regions if it is available, as far south as Florida and as far west as Ohio. The New York City users start bidding up the price of electricity to attract it to New York City, and it very often gets to $1.00 per kilowatt hour. In the preceding example in which the warehouse was using 648 kilowatts, which we will assume lasted for eight hours during the peak, the cost for electricity would be $5,184 (648 kilowatts x 8 hours x $1.00 per

kilowatt hour). This $1.00 per kilowatt hour is not unusual in open markets. People are installing diesel generators to cut off these super peaks (when electricity becomes very expensive). When the generator is operating, the facility will draw that much less power from the utility. Many public refrigerated warehouses have these generators for emergencies to assure their customers that they will keep the products cold no matter what happens to their electric grid. Many will be installing them.

Open Markets

Various publications state that the US has a severe power shortage. The picture is considerably more complex than that. The shortages vary by regions and in some cases by neighborhoods. Shortages exist not only for generation but even more for transmission and distribution lines. The prices a warehouse will confront are very much a function of the specifics of that location. On a national basis, it is fair to say that these superpeaks of $1.00 per kilowatt hour or so exist for anywhere between 100 and 400 hours a year depending on how hot a summer is, the region of the country, etc. It is only for this very few number of hours that the system is in severe shortage and prices get so high. The rest of the year the generation costs for electric power are only about 3 cents per kilowatt hour.

Alternating Current

In the US, electric power purchased from the power grid is AC or alternating current power. This means that the power comes in the shape of a sinusoid. The voltage and the amperage both follow this sinusoidal pattern. When the electricity arrives at your building, it confronts a variety of mechanisms which tend to shift the current-voltage relationships so that they are no longer exactly the same. When that happens, the power is no longer equal to the voltage times the amperage because during some intervals the power is negative, the voltage is positive, and the amperage is negative (or vice versa). Those periods do not produce useful power, and utilities will charge a premium, as mentioned in the next chapter, for this lack of synchronization or this power factor.

The power coming to the warehouse is actually three-phase, which means three lines of electricity each bringing its own sinusoid. Each sinusoid is 120° out of phase with the preceding sinusoid. The total length of the cycle of the sinusoid is considered 360°, so simply divide the total phase into three parts and each sinusoid starts at those points. That is what is meant by three-phase power. One can buy a single-phase motor or a three-phase motor; usually larger motors are three-phase. When three-phase power is measured with an ammeter, certain amperes are read on each leg. The total power of a three-phase system (in kilowatts) is equal to the voltage times the amperage times 1.732 divided by 1000. For a single-phase motor it would be voltage times the amperage as previously discussed.

The capacity of compressors is normally adjusted within the compressor. For instance, as discussed in earlier sections on refrigeration, a slide valve or a service compressor can be opened and closed causing the compressor to produce more or less tonnage. A reciprocating compressor tonnage can be reduced by "shorting out" cylinders. For instance, a 16-cylinder can be "shorted out" to 12 cylinders. Screw compressors particularly don't "unload" very well—they are much more efficient at full load than part load. To match the refrigeration capacity of a compressor with the load required by the refrigerated space is sometimes more efficiently accomplished by variable frequency drives. The speed of the motor is dependent on the frequency of the sinusoid. Power in the US is 60 cycles per second. That will generally drive a motor at 3600 rpms, 1800

rpms, 1200 rpms, etc. The speed of the motor can be changed by changing the frequency of the sinusoid coming to that motor with electronics; then it is called variable frequency drives. By changing the speed of the motor through changing the frequency of the drive, the refrigeration capacity can be adjusted more efficiently. However, variable frequency drives are costly. Some people are adopting them as more efficient methods of controlling refrigeration capacity.

Minimizing Power Costs

Gerard N. Von Dohlen

Basic Refrigeration

To operate a PRW effectively, one must have at least a rudimentary understanding of a refrigeration system. A refrigeration system is a heat pump that pumps heat from inside the refrigerated space to outside the refrigerated space. Picture a water pump. If the pump is required to lift water from 40 ft (12 m) above sea level to 180 ft (54 m) above sea level, it will require a certain amount of power to move a gallon of water. If one tries to pump water from 20 ft (6 m) below sea level (i.e. -20 ft or -6 m) to 180 ft (54 m) above sea level, more power will be required because the pump has to move the water a greater vertical distance.

Refrigeration is something like that. The lower the temperature in the room, the more power it takes to move a specific amount of heat from the room to the outside. The warmer the temperature outside, the greater amount of power is required to move any given amount of heat.

In the US, the quantity of heat is typically measured in British Thermal Units, or BTUs. A BTU is the amount of heat required to raise one pound of water one degree Fahrenheit in temperature and is equal to 1.055 kilojoules (kJ) in the metric system. One refrigeration ton (RT) of cooling is the ability to remove 12,000 BTUs (12.66×10^6 J) in one hour. For instance, air conditioners in hotel rooms are almost always one ton units.

When an air conditioner or refrigeration unit cools air, it performs two kinds of heat removal, sensible and latent. Sensible heat removal is simply reducing the temperature; latent heat removal is removing moisture. Latent heat removal involves converting the water vapor in the air to liquid water, which is the water dripping out of the air conditioner, known as condensate. In a refrigerated warehouse, when temperatures are maintained at 0°F (-18°C), that water vapor is converted from vapor to water and almost immediately to ice. This conversion from vapor to water to ice consumes a lot of energy: about 1,250 BTUs (1.3×10^6 J) per pound of water compared to one BTU (1055 J) required to reduce the temperature of one pound of water by 1°F (0.55°C). Ice on evaporators, ceilings, doors, and floors costs money. Furthermore, the ice has to be removed from almost any place it occurs. As we will discuss, removing ice also costs money.

This heat pump (that is, the process of removing heat from the room to the outside) is almost always powered by electric motors. Other options exist (namely, engine driven compressors), but they are still relatively rare in our industry. Electricity does not cost the same amount every hour of the year; in fact, under electric industry restructuring, electricity may have a different price every hour of the year. If a warehouse is in a restructured market (and almost all markets will eventually be restructured), it will literally confront 8,760 prices per year, varying from less than one-half cent ($0.005) per kilowatt hour (kWh) to more than $1.00 per kWh. Even in traditionally regulated markets, the cost per kWh of electricity during peak hours is far greater than it is during off peak hours. Therefore, in both traditionally regulated and restructured markets, when the refrigeration system is operated has a large bearing on the

cost of power to drive that system.

Maintaining Correct Temperature

Freezer temperatures are generally maintained at 0°F (-18°C), and ice cream is normally stored at about -15 to -20°F (-26 to -29°C). Reducing room temperatures lower than 0°F (-18°C) imposes a very significant cost premium.

Effect of Lowering Temperature on Cost

Room Temperature	Suction Temperature	kW/ton (Vilter-R22 at 80°F or 26.7°C Cond.) (kW/kW)	Cost	Cost Increase
0°F (-18°C)	-20°F (-29°C)	1.3 (0.37)	100%	
-10°F (-23°C)	-30°F (-34°C)	1.7 (0.48)	131%	77%
-20°F (-29°C)	-40°F (-40°C)	2.3 (0.65)	177%	31%

Effect of Lowering Temperature on Power Consumption

Room Temperature	Suction Temperature	kW/ton (Vilter-R22 at 80°F or 26.7°C Cond.) (kW/kW)	Capacity	Capacity Reduction
0°F (-18°C)	-20°F (-29°C)	135 (974)	100%	
-10°F (-23°C)	-30°F (-34°C)	118 (414)	87%	13%
-20°F (-29°C)	-40°F (-40°C)	108 (380)	80%	20%

Lowering the storage temperature from 0 to -10°F (-18 to -23°C), will cause an increase in power consumption of approximately 31%—a significant increase. To drive the room temperature down to ice cream storage temperatures, the power consumption and cost premium can go up to 77%.

The reasons for the increased power consumption are twofold. A compressor becomes a less efficient pump when the suction pressure (and temperature) goes down in relationship to the head pressure (and temperature). The head pressure is the system pressure at which the gas condenses to a liquid. The greater the pressure difference between the suction pressure and the head pressure, the less efficiently the pump operates. Secondly and more importantly, the lower the suction temperature, the lower the density of the gas, meaning that a given cubic foot of gas will weigh less. Since it weighs less, it has less ability to refrigerate.

Each warehouse must determine the temperature at which rooms should be maintained. Lowering the temperature may make the customers happier, but the question is whether the customers are willing to pay premiums for those lower temperatures. Usually, they will in the case of ice cream; but, in many other cases, they will not. Anyone who has spent any time in the freezer also knows that human beings can feel the difference between and 0 and -10°F (-18 and -23°C). Worker productivity is reduced as the temperatures get lower.

In addition to consuming more energy, the compressors also lose capacity. That is, gas getting

thinner and thinner means that a compressor with a given rated capacity will produce fewer tons of refrigeration. Going down an additional 10 degrees F from 0 to -10°F (-18 to -23°C) reduces compressor capacity by 13%; further reducing to -20°F (-29°C) reduces compressor capacity by 20%. Therefore, a 25% larger refrigeration system is required to reduce the temperature to -20°F. The cost of that refrigeration system will be approximately proportional to its tonnage. Therefore, when running a warehouse, try not to drive your temperature down below that which your customers' products require.

Keep Heat Out of the Room

Doors

Infiltration through doors causes a major loss of refrigeration. When a door is opened, the cold air from the room falls to the floor and rolls out onto the dock. Anyone working in a freezer during the summer has seen clouds of moisture moving out along the dock. If air did not go back into the refrigerated room, the room would obviously develop a vacuum, and that does not happen. Therefore, the air that rolls out along the floor is replaced by air entering at the top of the door. Stand in any freezer, look up at the ceiling right above the door, and look at the ice resulting from warm, moist air rolling in the room. Because the air entering is warmer than the room temperature, it goes directly to the ceiling. Remember that the presence of ice costs a lot of money and it must eventually be removed, which costs more money.

A variety of different door types are available. The doors listed and described below are commonly used to enter freezer or cooler rooms.

- **Fabric rollup doors** are very fast and roll up when a photo eye senses an approach to the door. They are generally used in coolers, not freezers. They can be effective, depending on traffic and temperatures.

- **Rigid panel rollup doors** are similar to fabric rollup doors but are made of rigid panels. They typically do not have a high R (insulating) value, but can be used in freezers.

- **Horizontal single pane sliding doors or horizontal bi-parting sliding doors** are simply insulated panels that move back and forth to close or open. This is the most commonly used type of door.

- **High speed doors** are available that operate as fast as 6.5 ft/s (2 m/s). Therefore, a bi-parting door with each panel approximately 5 ft (1.5 m) wide can open in one second. High speed doors cut down on infiltration and are quite useful and common in PRWs.

- **Strip curtains** are quite effective, although operations people do not like them because they hit people entering. The best strip curtains are wider, 12-in (30-cm) curtains, generally ribbed, with 100% overlap. They are functionally two sets of strip curtains mounted so that the joints of one row are aligned with the centers of the strips in the second row. Sometimes people "picture frame" strip curtains to avoid having the strips hit the drivers. That is, some of the center strips are cut to the height of the forklift truck, creating a doorway within a doorway. When used with high speed bi-parting doors, the system is quite effective.

- **Lightweight strip curtains** are generally used for pedestrian doors which enter refrigerated spaces.

- **Anterooms or vestibules** are often used to reduce infiltration between docks and refrigerated spaces. These are structures about the size of a door and 10 ft (3 m) long, usually with a hard door on one end and strip curtains on the other. Sometimes strip curtains are used on both ends. The air entering the vestibule does not flow in a regular pattern; it mixes inside the anteroom, which breaks up the cold-air-out hot-air-in flow pattern. Also, the anteroom is generally long enough so that the door behind the forklift closes before the one in front of it opens, which obviously is the case with strip curtains. Vestibules take space, but if racks are installed on the dock wall vestibules can usually be installed without using additional space.

- **Dual air curtains** have been developed in recent years, usually with horizontal air flow. The advantage of these designs obviously is that nothing moves—the forklift simply goes through the air curtain. Air curtains require a significant amount of energy to operate and are expensive to install, but they have the advantage of the appearance and convenience of a completely open door.

Each warehouse makes a decision about strip curtains, but they are quite cost effective. Some people use bi-folding doors, which are essentially strip curtains that "sort of rotate" and open, to avoid the problems associated with strip curtains.

Doors can either be operated manually or activated by electric eyes, a photo eyes, motion detectors, presence sensors, etc. They can also be operated by a loop that senses the metal in the forklift as it passes over. These systems, which do not rely on the operator, are worth investigating. Telling forklift drivers to close doors is a recurring, unpleasant, and unproductive pursuit. A more extensive discussion of doors is included in the IARW *Energy Conservation Manual*, portions of which have been extracted for this article.

The moisture content of the air which infiltrates the room is extremely important. On hot, moist days the moisture content of the air is much greater than on cooler, drier days. For instance, on a 90°F (32°C) day at 80% relative humidity, air will contain 6.5 times more water than on a 50°F (10°C) degree day at 50% relative humidity. Keeping doors open on a hot humid day is an immense strain on the refrigeration system. Moisture, as we know from the preceding discussion, forms ice on the evaporators which costs a lot of money to remove.

Typically, hot gas from the high pressure side of the refrigeration system is piped into the evaporator to remove frost. That hot gas reaches high temperatures (140-180°F or 60-82°C) and melts the ice. The ice drips into the condensate pan and is drained out of the room. However, hot gas is not free. Electric power is used to create it, and all of the heat put in the room to melt the ice must be removed again by the refrigeration system. This process of building ice and then removing it is very expensive. Keep water vapor out of your rooms. Get good doors and keep them closed. Use automated actuators or discipline the workforce. Do whatever is necessary to keep infiltration through the doors to a minimum.

Lights

Artificial light is necessary to see in a freezer or cooler. Every kilowatt that goes into that freezer to create light costs money, and it also costs money to remove the heat the lights generate. A 1,000-watt light requires 3/10 of one ton of refrigeration (1.05 kW) to remove its heat. Refrigeration systems typically require 2 kilowatts per ton (0.57 kW/kW) , so 3/10 of one ton (1.05 kW) will require 0.6 kilowatts. A one-kilowatt light (1,000 watts) requires 0.6 kilowatts of refrigeration to remove the heat it produces. Therefore, that light does not cost one kilowatt—it costs 1.6 kilo-

watts. Some systems turn off lights in unused aisles and others reduce lights from 100% to 50% or so; these systems pay dividends. Turn the lights off when they are not needed.

People and equipment also generate heat. Everyone has been in a conference or meeting room or at a birthday party with a lot of people. Often the air conditioning system has trouble pulling that heat out and the room gets warm. A person working in a 0°F (-18°C) room generates about 270 watts of heat. Think of each person as a 270 watt light bulb. Forklifts have batteries which release electricity to power their motors, and those motors generate a lot of heat. Generally, the machines will not be in rooms unless they are doing useful work, and one cannot stop doing work to reduce refrigeration load. Inefficient operations, with too many people and too many forklifts in a room, also tax the refrigeration system.

Leaks

Seal leaks around doors and leaks in corners of buildings should be fixed immediately. Some are easier to find if they are in a freezer or cooler, since ice or water forms (drips, puddles, etc.) as a result of condensation. Systems exist for filling holes including new seals, urethane kits, etc.

Stacking Product

Evaporators work by blowing air over coils whose temperature is lower than the air, therefore reducing the temperature of the air. Choking that air flow makes the evaporator less effective (that is, it transfers less heat from the room to the refrigerant). Try to keep the air flow through the evaporators as unrestricted as possible by not storing product on either side of the evaporators.

Defrosting Coils

As ice forms on the coils, the space between the coils gets smaller and, at some point, disappears. The fans cannot blow air through ice. The ice chokes off the air flow and reduces the refrigeration effect to almost zero. Some warehouses have automated systems to detect the frost and adjust defrost cycles accordingly. In any case, make sure that the defrost cycles occur frequently enough and are long enough to remove the ice. The defrost cycle should be no longer than necessary, or the heat required to remove the ice will be excessive and the evaporator will not be producing refrigeration.

Building Colors

Use white colors, particularly on roofs. The sun transmits heat to the earth through radiation. Stand in the sunlight and you can feel its radiant heat. That radiant heat also heats the roof of a warehouse; it heats the sides of the building as well, but the roof has the heaviest load. The temperature on a black roof reaches 180-190°F (82-88°C). Those temperatures can be reduced significantly by painting roofs or panels white. Specialized paints are available, as are white acrylic paints. If you have a dark colored roof, odds are you can save power by making it a light colored roof. There is a section in the IARW *Energy Conservation Manual* which covers this topic more thoroughly.

Head Pressure

After the compressor in a refrigeration system compresses the refrigerant gas, that compressed gas moves to a condenser, usually an evaporative condenser. An evaporative condenser is sim-

ply a series of rows of refrigerant pipes with a fan underneath and water pipes with spray nozzles on top. The nozzles in the water pipes spray water down onto the refrigerant pipes containing the hot refrigerant gas. This spray of water evaporates and reduces the temperature of the air flowing through the evaporator from the "dry bulb" temperature to the "wet bulb" temperature.

When air isn't completely saturated with water, its temperature can be reduced simply by evaporating water. The lower air temperature reduces the pressure of the refrigerant gas in the pipes so that the gas is converted into a liquid at a lower pressure and a lower temperature. The lower the pressure and temperature at which this condensation takes place, the more efficiently the refrigeration system operates. For example, reducing head pressure by 10 pounds per square inch (68.9 kPa) or about 30°F (1°C) generally reduces power consumption by about 25%.

Condensers must be properly maintained and operated to work effectively. Generally, condensing should be taking place about 10 degrees F (5.5 degrees C) above the wet bulb temperature. If condensing is occurring at a higher temperature, either the condensers are too small, they are clogged, the fans aren't operating, the spray is not operating properly, etc. Maintain condensers properly. Make sure they are operating properly, particularly before the summer heat hits.-

Refrigerated Docks

Many, if not most, PRWs refrigerate their docks. Some docks are maintained at relatively low temperatures (around 40°F or 4°C); others are maintained at a constant temperature difference with the outside temperature. No standard exists, so dock temperatures vary considerably. Docks are refrigerated primarily to protect the products being transferred across them. Even if a dock is well refrigerated, products must move quickly on and off of them. Because products will increase in temperature if left on a dock, more damage is done to refrigerated products on docks and trucks than inside a freezer or cooler. Products with low thermal mass need to be moved particularly quickly. For instance, frozen dough or pastry products may weigh only 3-4 ounces (85-113 grams), have very low thermal mass, and will defrost quickly. Fifty-pound (23-kg) blocks of meat or shrimp don't defrost very quickly. Ice cream obviously must be moved into a pre-cooled truck as soon as possible because crystals will form and ruin the product.

Keeping docks properly refrigerated requires operational effort. The door seals must be in good condition and the trucks must fit those door seals. A variety of door seals are available to handle shorter trucks and some warehouses use city doors (doors with dock seals lower than on the tractor trailer doors) to handle straight trucks, etc. Some have unrefrigerated sections of "city docks" to handle small vans and trucks. Obviously, doors must be closed before trucks pull out, and interlock mechanisms are available to prevent the truck from pulling away until the door is closed. Many dock workers like to leave doors open to direct trucks as they back up. That is not an acceptable practice with refrigerated docks, particularly in the summer. Many refrigerated docks have vertical dock plates, so that the dock door is able to rest on the lower level of the dock floor and seal properly. When pit dock plates are used, air leaks in through the pit and around the dock plates. Seals are available for pit dock plates to reduce that infiltration and they should be installed and maintained. Vertical dock plates have vertical up and down movement of generally 6 in (15 cm) up and down, whereas pit dock plates generally will go up and down 12 in (30 cm). If a warehouse services a large variety of trucks, the vertical door plates may not be able to drop down low enough or rise up high enough.

An advantage of refrigerated docks is that the air temperature is reduced, as well as the moisture

content of the air, at higher suction pressures which requires less electricity. That is, the removal of the moisture, for instance, from the air on the dock requires less power than the removal of that moisture once it has entered the freezer. Docks normally have doors every 12 ft (3.7 m), and doors are not as good as walls for preventing refrigeration losses. Door seals, dock plate seals, closing dock doors, closing pedestrian doors on docks, a disciplined workforce, and consistent maintenance of the docks are essential if the refrigeration system is going to be effective and operate at a reasonable cost.

All of the above discussion deals with reducing the amount of heat the refrigeration system needs to remove from the refrigerated space to maintain any given temperature.

Purchasing Electric Power

This section deals with buying the electric power required by the refrigeration system at the lowest possible price. Very significant cost savings are available with intelligent purchasing. Warehouses buy power under one of three sets of conditions: (1) completely regulated, (2) in some stage of restructuring and re-regulation, or (3) completely restructured and re-regulated.

In a traditional regulated world, the local public utility generates, transmits, and distributes power to the users. The utility may be buying power from other utilities or generators or perhaps selling power to them. The price the user pays is governed by some form of a public utility commission, and the tariffs are published. The voltage of the power you use is generally reduced from the line voltage in the street by a transformer. Either you or the utility own that transformer. If you own the transformer, you buy primary power; if you do not own the transformer, you buy secondary power. Primary power is generally cheaper, to compensate the owner of the transformer for the cost of ownership. A company owning its own transformer earns a reasonable rate of return; that is, the lower electric prices compensate for the other costs of ownership.

Every utility has a different pricing system, or formula, and these pricing systems tend to become extraordinarily complicated. Reading a power bill can become a trying, difficult, and frustrating exercise.

Electric Consumption

The bills usually contain several charges, the first of which is usage. Each warehouse is charged for the total number of kilowatt hours (kWh) consumed. Somewhere in your building are one or more kilowatt hour meters which record the total number of kilowatt hours consumed. The usage charge usually depends on the time of day as well as season of the year. The charge is highest during the middle of the day in the summer and lowest at night in the winter.

Demand Charges

The next major charge is generally called demand. Demand is based on the maximum kilowatt demand metered over a short interval (normally 15 minutes) in a one month billing period. The meter indicates the average kilowatt demand during the 15 minute interval of highest demand anytime during the month. That measurement is the billing demand. Demand is normally measured on peak, off peak, and often during intermediate time periods.

Some utilities use demand "ratchet charges." For instance, if you use 1,000 kilowatts (1 mega-

watt) during any 15 minute interval in August, that demand may set the demand charge for every month for up to one year. Obviously, one needs to be very careful about setting that demand charge. The object behind demand charges is that the utility needs to provide generating capacity and transmission and distribution capacity to supply the maximum usage. Demand charges in the PRW industry are generally one-quarter to one-third of the power bill. Demand is important and can be minimized.

Quantity Discounts

Some utilities have lower rates for larger power users. Some of these rates are staggered; i.e., one has a certain charge for the first 10,000 kWh and a lower charge for the next 10,000 kWh. This pricing is sometimes known as "block pricing," which refers to the sale of successive blocks of power at different prices.

Fuel Adjustment Charges

Fuel adjustment charges allow utilities to charge you more or less, depending on the price they pay for fuel, relative to the price which was factored into their last commission-approved rate.

Power Factor Charge

Another charge which is difficult to understand is a power factor charge. The power we buy is alternating current (AC), and both the voltage and the amperage have the shape of a sinusoid. If these two sinusoids are identical (two sinusoids laid down on top of each other), the system has a power factor of one and no premium is charged. Because of the physical properties of motors, capacitors, etc., these sinusoids shift out of synchronization and, at some point in the cycle, the voltage will be positive and the amperage may be negative or vice versa. During that interval when the voltage is positive and the amperage negative, no useful power is being measured. The utility is supplying voltage but not amperage at the same time and, therefore, no kilowatts are being recorded. The utilities want to charge a penalty for "low power factors" because they believe that they are providing a service for which they are not being compensated. Some utilities measure power factors and charge for them while others do not. Some utilities require customers with low power factors to implement power factor correction to correct or minimize the problem.

Interruptible Power

Some utilities will give discounts to customers able to partially or completely reduce service during a prescribed period. A typical situation would be in the summer, during the middle of the day. A utility will call and give a customer a few hours notice to reduce demand by a pre-agreed percentage or by a demand increment. If the customer has standby generators, the utility may call the generators, turn them on, and run them during this period. Reasonable savings can be obtained by the use of standby or backup generators, which allow customers to take advantage of interruptible power rates without actually interrupting or curtailing business activities. Refrigeration equipment sometimes can be throttled to save power.

Sample Bill

At the top right is the analysis of a month's power usage of a PRW which uses engine driven compressors for refrigeration. As a result, its power demand, consumption, and costs are much

Metered Use Combined				
Service Charge	53.57			$368.44
On Peak kWh	36,000.00	x	0.08532	3,071.52
Intermediate kWh	5,200.00	x	0.07556	392.91
Off Peak kWh	33,200.00	x	0.06596	2,189.87
On Peak kW	124.00	x	8.56000	1,061.44
Intermediate kW	96.00	x	1.05000	100.80
Off Peak kW	116.00	x	1.05000	121.80
Energy Adj/kWh ($0.0094750 CR)				(704.94)
TOTAL				**$6,601.84**

lower.

This bill is for a public refrigerated warehouse in Newark, New Jersey. The utility is PSE&G and the bill is for the period July 1998. The first small charge is a standard service charge, which recovers some fraction of the fixed costs of distribution service, including meter reading and billing.

The second charge is "On Peak kWh." During this period, the warehouse consumed 36,000 kWh during the peak hours, which are 8:00 a.m. to 10:00 p.m. Monday through Friday. The charge is approximately 8½ cents per kilowatt hour, resulting in an on-peak kilowatt hour cost of $3,071.52. The "Intermediate" period is weekends (Saturday and Sunday), and the consumption is relatively low. "Off Peak" is primarily 10:00 p.m. to 8:00 a.m. Monday through Friday.

The "On Peak kW" is the demand during peak hours from 8:00 a.m. to 10:00 p.m. Monday through Friday. The demand charge in this case is $8.56 per kilowatt and the facility required 124 kilowatts. As mentioned earlier, this facility uses engine driven compressors and is only 1.6 million ft^3 (45,000 m^3). The demand charges are $1,061 for on peak demand. The intermediate and off peak charges are far lower, only $1.05 per kilowatt.

The energy adjustment is negative. Apparently the utility was buying fuel at lower than expected costs.

The total electric bill for this facility is $6,601.84. The facility used 74,000 total kilowatt hours, the sum of on peak, intermediate, and off peak kWh. During this month, the average electric cost was 8.9 cents per kilowatt hour. The US national average is around 7 cents. The demand charges for this particular period were only 19.4% of the total bill, or $1,284.04. The reason the demand charge is so low is that the electricity is used primarily to operate a well pump to deliver water to the condensers and a second pump to circulate brine throughout the warehouse. The other uses include lights, four elevators, and battery chargers. If this facility had used its maximum demand of 124 kilowatts for 24 hours per day and for 31 days during this period, it would have consumed 92,256 kilowatt hours. It consumed 74,400 kilowatt hours, or 81% of the total possible usage defined by the demand (124 kW x 24 hours x 31 days). That is an unusually good relationship between consumption and demand (load factor). Most public warehouses

would probably have demand charges between 25% and 33% of their total electric costs, since their load factors would be lower.

Get a copy of your power bills and make sure you know how to read them. If you don't, ask your public utility representative or someone in the industry to help you. You can't control a cost you don't understand.

Maintain a spreadsheet by month with these columns:

1. Month
2. Total Electric Costs
3. Peak Usage
4. Intermediate Usage
5. Off Peak Usage
6. Peak Demand
7. Intermediate Demand
8. Off Peak Demand

A clerk can fill this out for you. Look for trends and compare a current month to the same month last year. Check for billing errors (surprisingly common) and unexplained rate changes. Investigate any major changes in consumption. Look for ways to reduce demand, such as not turning compressors on during peak demand periods. The start up significantly increases demand. Shift loads to lower cost hours.

Shifting Demand

Whether a facility is served under a public utility tariff or in the free market, peak power is much more expensive than off peak power. A significant savings can be realized by shifting power consumption from peak hours to off peak hours. Reducing the operating level of a refrigeration system during peak hours is quite common in the industry. Air temperatures in the room will rise, but changes of 2-6°F (1-3°C) are not likely to translate into rises in product temperature, particularly when those higher air temperatures do not persist for long periods. When the power costs are lower (generally at night), the refrigeration system can be run to its capacity and temperatures reduced below 0°F (-18°C).

Recent research by WFLO has confirmed the earlier research by the US Department of Agriculture that temperature variations of this magnitude do not adversely affect product quality, provided the appropriate average temperature is maintained. Each warehouse must decide how aggressively demand shifting will be used. It depends not only on the difference in power rates, but also on how active the warehouse is, how often the doors are opened, how well it is insulated, the excess capacity of the refrigeration system, etc.

At night, temperatures are lower and, therefore, condensing temperatures are lower. Lower condensing temperatures increase the efficiency of the refrigeration system. An earlier chart demonstrated that lower suction temperatures increase power consumption. Head pressure reductions have about the same proportionate effect as suction pressures. That is, if condensing temperatures are 10°F (5.5°C) lower at night than during the day, power consumption will be reduced by approximately 25%. To create lower temperatures in the room, compressor suction pressure must also be reduced, often by about 10°F (5.5°C), which increases power consumption. The system at lower suction pressures and lower head pressures is approximately as efficient at night as it was during the day, and the savings result from paying a lower price for power consumed. For instance, in the previous power bill analysis, the off peak kilowatt hour usage was about 23% cheaper than the on peak kilowatt hour usage charge. That difference is much larger in some areas.

Some warehouses have automated systems that are programmed with the hours, rates, and decision formulas. For instance, in the previous chart, the peak power hours were 8:00 a.m. to 10:00 p.m. The whole system would therefore be instructed to start up compressors at 10:01 p.m. and shut them off before 8:00 a.m. Some utilities have a "ratcheted" demand charge, in which case the system would be carefully programmed not to allow demand to exceed a certain amount because that demand charge could persist for up to a year. Each utility is different; therefore, the specific method to optimize power costs in any given utility will be different.

Buying Electric Power on the Open Market

The vast majority of PRWs buy power from their local utilities, which may or may not be restructured and re-regulated. In many areas, purchasing power on the open market is a viable alternative. In each area, either an ISO (independent system operator) or an RTO (regional transmission organization) creates orderly electric markets, and power can be purchased in that context. ISOs and RTOs have price zones; that is, the price for electricity at a specific location is based on the cost of delivering power to that location. For instance, some of the data in this article is from the PJM ISO at the Connectiv Zone and some at the PSE&G Zone.

Power can be purchased on an hour-by-hour basis, and the price changes each hour. Prices fluctuate a great deal. For the six summer months of May through October in 2001, the average price per kilowatt hour on the Connective zone of the PJM ISO was 4.19 cents per kilowatt hour. That is the price a user would have paid to consume 1 megawatt continuously during that time period. The open market buyer would also be charged an ICAP (Installed Capacity Charge) based on the rate at which power was consumed during the five hours with the highest demand occurring during a calendar year. The current year's charge would be based on last year's highest five hours. Therefore, someone buying in the open market is heavily motivated not to let the demand in those five hours get very high.

One way to reduce demand is with a generator; another is through load management. The ICAP charge would be about $40 per megawatt day. For instance, if the highest five hours demand in the preceding year were 600 kilowatts (or six-tenths of a megawatt), one would pay 6/10 x 40 x 365 days, or approximately $8,760. Power has to be transmitted from that zone to you, and that charge is about $42 per megawatt day, calculated virtually the same way as the ICAP charge. So when the ICAP is added to the transmission charge, cost doubles from about $9,000 to about $18,000 for someone demanding a maximum of 600 kilowatts. Those charges would be about $15,000 each for a 1 megawatt demand, or $30,000 total.

Buying in the open market creates two opportunities for cost savings which are generally not available when purchasing under a tariff. Loads can be managed every hour. For instance, instead of facing a 14-hour demand charge (in New Jersey the period from 8:00 a.m. to 10:00 p.m. Monday through Friday is the peak demand period), loads can be managed for much shorter time periods. Utility tariff demand charges are based on a very small time sample. For instance, the highest 15 minute usage is the monthly demand in New Jersey. It is very difficult to load manage against a 14-hour time period when one 15-minute period determines a whole month's (or with a demand ratchet, a whole year's) demand charges. Compressors and evaporators must be shut off, or substitute diesel generators operated, for all 14 hours every weekday or demand charges won't be reduced.

If generators are operated for six months, 14 hours each weekday, 1,820 hours of operation occur, which far exceeds the 500 hours permissible in New Jersey. Therefore, trying to demand

manage against a 14-hour demand period with a 15-minute measurement period is virtually impossible. Temperatures need to rise considerably, generators using natural gas and/or emissions controls must be used, and no downtime can take place during the peak.

In the open market, that is not the case. During the six months May through October 2001, if one used a 7.5 cent strike price (the price above which one would generate electricity), electricity would have been generated for only 400 hours. That is, for about 400 hours May through October 2001, electricity costs more than 7.5 cents. Because the prices are fluctuating for one hour intervals during the day, a well-written computerized system can anticipate these price increases and control demand by shutting some compressors down, shutting some evaporators down, or perhaps shutting all compressors and evaporators down, but for no more than two or three consecutive hours.

Therefore, average room temperatures can be maintained without having to pull very low suction pressures during the hours when refrigeration operates. That is, if one wanted to average 0°F (-18°C) and shut compressors off for 14 hours a day, five days a week, very low suction pressures would be required during the remaining 10 hours so that refrigerated rooms maintained a specific average temperature. Remember that reducing suction pressure by 10°F (5.5°C) decreases compressor capacity by 30-35% and increases horsepower per ton by 20-25%. However, if the compressors and evaporators were only turned off for 3 hours and the temperature rose 5°F (2.8°C) during those hours, one would only have to pull temperatures for the other 21 hours about three-quarters of one degree below zero in order to average 0 degrees (-18.2°C to average -17.8°C). Therefore, demand management in the open market is a much more viable option than it is in a tariff market.

If one simply buys power in the open market without demand management, in all probability savings would be minimal. For instance, during the May through October 2001 period, the delivered cost of electric power bought from the open market for a PRW using 600 kilowatts would have been almost exactly the same as the utility's tariff. That is, the cost from the regulated utility during those six months would have been about 8.2 cents per kilowatt hour and from the open market virtually the same number—8.1 to 8.3 cents, depending on some other variables. Therefore, going to the open market in an unmanaged manner is not likely to produce significant cost savings. If a generator were present and power was generated for the 400 hours when the market price exceeded 7.5 cents per kilowatt hour, about $38,000 would have been saved over six months and about $57,000 over the full year. The generator necessary to save that $38,000 would cost about $450,000. The generator would have returned about 8.4% cash on cash return, just from shaving those peaks. When that peak shaving is combined with power management at lower electric prices, the savings can be quite significant.

The generator provides insurance against wildly high electric prices, which will exist in the market if simple-cycle turbine peaking generators come on line. When all costs (fuel, operations, and capital) are paid, simple-cycle turbines cost about 14 cents per kilowatt hour because they are not operated very much (sometimes only 80 or 90 hours a year) and the capital recovery rate is very high. Simple-cycle turbines consume a great deal of natural gas because their thermal efficiencies are only around 22%, ± 3%. If a natural gas gen-set or a diesel generator with ammonia injection is purchased, the ability to manage fuel sources becomes that much greater, since the generator may be operated for more hours during the year without violating emissions regulations.

Systems are available which monitor open market electric prices continuously and can com-

municate with virtually any control system in a PRW. Such systems carefully analyze electric consumption, as well as temperatures in the rooms and the responsiveness of temperatures in the rooms to various levels of refrigeration at various points in time. When those trade offs are understood (how long one can shut off, how much refrigeration is available for recovery, what temperature rise is experienced, etc.), then a model of the particular warehouse is built. Based on that model, first evaporators are turned on and off, then compressors are turned on and off to match that evaporator change. Generators can also be turned on and off. The PRW specifies the average temperature to be maintained and the maximum variability that is tolerable for any given period of time. The system monitors room temperatures and the operating conditions of the compressors and evaporators, as well as the free market prices. It then attempts to operate the refrigeration system to minimize electric cost within the prescribed rules.

Can You Save Money Without Turning a Generator On?

When purchased on the open market, electricity has a different price each hour of the year. The prices vary quite considerably during any given day. For instance, in the month of August 2001 at 1:00 a.m. the electricity averaged 2.28 cents per kilowatt hour. At 3:00 p.m. it averaged 15.4 cents per kilowatt hour. The overall average for the month was 6.4 cents. If a control system can "load shape" by shifting electric consumption away from expensive hours towards less expensive hours, the average price for electricity can be driven down quite considerably.

As long as the refrigeration system has excess capacity, it can be throttled down during the high priced hours and run harder during the lower priced hours. The system is only short of capacity on design days; that is, generally, something like 78°F (25.6°C) wet bulb temperature. On design days, a system which combines a control system with a generator would run the generator and not attempt to throttle the refrigeration system. On non-design days, the load can be throttled during some hours of the day.

The control system has to know how much temperature rise is tolerable for a warehouse, how long it would take under those operating conditions to reach that maximum temperature rise, how long equipment can be throttled and still have enough capacity to produce the required ton hours to keep the average temperature at zero or below, etc. Such control systems do exist; Icetec is one. The system has some complex decision rules that look at the time of day, the temperature outside, the price of electricity, the recent pattern of that price, etc. and attempts to buy more electricity when it is cheaper and less electricity when it is more expensive. It generally does that by shutting down evaporators. Most compressors will automatically unload when the evaporators are not placing a load on the system. A modern system will observe air temperatures at various places in the room and turn the evaporators back on before that air temperature becomes unacceptable.

During many months of the year (for instance, January), the system can easily be throttled during those hours when electricity is very expensive (usually 1-6 hours) and then run up to capacity during the other hours. The price differences can be quite substantial. For instance, at 7:00 p.m. on January 3, 2002, power cost 4.58 cents per kilowatt hour. Five hours later it cost 1.4 cents per kilowatt hour. For a period on January 3 from 6:00 p.m. until about 10:00 p.m. the power cost was above 4 cents per kilowatt hour. For the seven hours preceding that it was below 3 cents and for the nine subsequent hours it was also below 3 cents. If the system could anticipate that, electricity costs could be reduced.

Icetec has developed one such system. When combined with a generator, the system looks at

these variables at any given point in time and decides how much refrigeration will be produced. If power is cheap, the system is operated close to capacity; if electricity is expensive, satisfying that load is postponed to when it is less expensive. When the real peak prices occur, the system turns on the generator because peak electric costs normally occur when the weather is hot. Therefore, electric costs are reduced because, in the intermediate periods, the load is "shaped" and, in the very high cost periods, diesel generators are used and the load on the electric grid is "shaved." The combined effect of using both of these techniques can be quite pronounced. The average cost of purchased electricity can be reduced by 30-40%.

For those who operate in areas where power can be purchased in the open market, this represents a very viable alternative. For those buying electricity from a utility, with prices based on their definitions of peak power periods, the refrigeration control system's ability to perform is significantly inhibited because the peak power hours (high demand hours) are quite long (for instance 8:00 a.m. to 10:00 p.m.). Throttling the system back is not a viable option for most warehouses for that length of time. Demand charges under those tariffs are usually measured by any 15-minute interval during the month. Although some money can be saved within utility tariffs by shifting loads to non-peak hours, all of these computer based control systems work much better against open market purchases than utility tariffs.

Logistics Excellence

Gary Hutchinson

Introduction

The past decade has proven to be an exciting time for logistics, with the re-engineering of the logistics pipeline and the birth of the terms Supply Chain Management (SCM) and Efficient Consumer Response (ECR). During this time, logistics issues have increasingly appeared on the desks of CEOs and CFEs.

Although companies are now realizing the potential savings associated with an efficient logistics network, many still do not realize exactly what logistics is. Because of this vague understanding, many companies rely on experts to tell them where the savings might be found in their own operations. Unfortunately, the use of experts has spawned a volume of industry buzzwords and a lack of understanding of what is necessary to achieve logistics excellence.

Logistics is more often thought of as a military term. Webster's Dictionary defines logistics as "the branch of military science having to do with procuring, maintaining, and transporting material, personnel, and facilities." The most successful military campaigns are those where the victor has a superior logistics network and has efficiently and quickly moved troops, supplies, and equipment.

Logistics in the business world is very similar to logistics in the military sense. As business leaders, we are constantly trying to find the most effective and efficient methods to utilize our resources. Logistics must be recognized as a key factor to a company's success. As in the military, logistics improvement methods require strategy and a definition of the major logistics fronts. Just as in a war, where each of the fronts must be worked in an integrated fashion, so too must we develop a strategy to work all of the logistic fronts. The five logistics fronts are:

- Distribution
- Third Party Logistics
- Information Technology
- Transportation
- Warehousing

The following subsections detail each of the fronts and the opportunities that exist in working on these fronts.

Distribution

To be successful in logistics, companies must map out global distribution opportunities. For many years, little attention has been paid to the methods of physical distribution, which was considered a process that only added cost, not value, to the product. Fortunately, this thinking has changed. Today there are many opportunities in distribution, including pull and push systems, customer service, network rationalization, inventory reduction, centralization, and strategic planning.

The first distribution opportunity is in the creation of pull systems based on the needs and demands of the customer. Point of sales (POS) information is captured at the retail level and used to determine replenishment requirements in the retail distribution channels. In effect, consumers are pulling demand through the chain as they demand the product.

In a push system, the manufacturing of goods is based upon obtaining manufacturing economies of scale. The product and quantities produced are based not on consumer demands but on manufacturing capabilities. As a result, the manufactured product is being pushed upon the consumer. Push systems are fast becoming outdated as the power in the distribution channel has shifted from manufacturers to retailers.

Every participant in the distribution channel must be able to support a pull system. The retailer must be able to collect and disseminate POS information and then transmit it to distributors and manufacturers. The distributors must be able to turn their inventory quickly and maintain high levels of inventory accuracy, as the retailer will be demanding just-in-time (JIT) delivery of merchandise. Manufacturers must be flexible and adaptable in their manufacturing process to provide the quick changes necessary to support pull technology. Like distributors, manufacturers must also be able to provide quick and accurate delivery of merchandise.

Customer service is another important distribution opportunity. Today, the term "customer service" can be confusing. Some of the most common misconceptions of customer service are that customer service is a smile or that the customer is always right. Instead, customer service is much more. In order to best serve customers, put yourself in their shoes and ask, "What does the customer want?" The logistics customer wants:

- Reduced costs
- Increased quality
- Teamwork/partnerships
- Responsiveness

Through understanding what the customer wants, you can build a better relationship that will result in long-term sales opportunities.

The third distribution opportunity is network rationalization. In the past, locating distribution centers closer to customers was a way to provide superior customer service. Today, population shifts, labor costs, and local business climates all contribute to the relocation and realignment of distribution networks. Also, the number of distribution centers was typically dependent upon the service level and the number of markets a company wanted to service. However, the key factors influencing these service levels were the time it takes to process an order and the cost and time to transport the product from the distribution center to the customer. The more efficient the processing of orders, the fewer distribution centers would be required. The key is to keep in line with these concerns and still provide excellent customer service, while keeping costs down by utilizing fewer centers.

With fewer distribution center locations, maintaining superior customer service is a challenge. Information technologies today make it possible to significantly reduce the time to process an order. Combine information technology with newer, more efficient storage and material handling technology, and what results is a design that can more quickly process and flow goods throughout the distribution center. As a result, a company can provide the same service levels but be even further away from the actual customer locations.

Savings can also be realized with the reduction of a company's distribution centers because less inventory, and subsequently less total storage space, is required. Reducing the number of distribution centers will also reduce total operating costs and make automated technology implementation easier. Relocation, combined with fewer and larger distribution centers, is providing companies with significant logistics savings.

The second factor that allows for distribution center consolidation is the successful deregulation of the transportation industry, which allows for better service and has created an overall more competitive environment. As a result, companies have been able to consolidate distribution operations, reduce their total transportation bill, and still meet their service requirements.

The fourth distribution opportunity is in inventory reduction. It is sometimes said that the best inventory is no inventory. Although low inventory levels are desirable, a standard level of inventory is required to ensure superior customer service. One reason for excess inventory is that many companies have too many distribution centers, so the total inventory information is masked because it is site-specific and not global in nature. Another reason is that companies do not have the information technology to support 100% accurate inventory. If a company's inventory is not completely accurate, buyers and inventory planners must protect their positions by carrying a little extra stock. Unfortunately, no one ever goes back and reduces "a little extra stock." As a result, inventory balloons.

There are many benefits associated with reducing inventory: smaller distribution centers, less working capital tied up in inventory, less obsolescence, and quicker response to changing customer demands and needs. All of these benefits are necessary if a company is to have a superior logistics network.

The fifth distribution opportunity is in centralization. For many companies, distribution has typically been site-specific. Today, we are seeing a centralized distribution process. With the new focus on centralized distribution has come the need to centralize buying, inventory management, order processing, and transportation management functions.

The sixth distribution opportunity is in strategic planning. For years, logistics was not included in business planning and was considered a non-value-added process. Companies are now beginning to realize that distribution is a key element of success and are developing five-year distribution strategic master plans. Finally, companies are coming to realize the importance of distribution to the total business environment.

Third Party Logistics

For many companies, logistics is considered a strategic strength, and a third-party provider may be used to augment an already efficient supply chain. For others, the third-party provider can be the entire logistics department, while the focus is on developing core technologies within the company. In these situations, a third-party provider has the necessary expertise and can manage the logistics network better than can be done in-house. There are many benefits possible with using a third-party provider, including cost-reduction, seasonality control, customer service, utilization, and shipment consolidation.

The first third-party opportunity is in cost reduction. Companies without the expertise to handle logistics in-house can avoid an inefficient logistics operation by either creating a logistics department or using a third-party firm to manage the logistics network. The challenge before go-

ing to a third-party provider is to be sure that this step will benefit the company financially.

Using third-party logistics can help to smooth product seasonality. One method is to manufacture and distribute products that complement the seasonality of one another. A company that distributes both snow shovels and lawn mowers can take advantage of the winter and summer seasonality of its product lines, allowing it to build a distribution network that does not have wide distribution swings. Unfortunately, instances like this are rare. Most companies do not have complementary product lines, and in most cases it doesn't make sense to build a distribution center that can handle the seasonality peaks. In these situations, a company should consider third-party logistics.

Third-party logistics providers can also provide the storage capacity that is necessary to meet the demands of seasonality or any irregular inventory demands. Third-party providers can provide storage for a new product launch or for an opportunity buy or any other sales strategy that requires a buildup of inventory prior to sale. In most cases, the use of a third-party provider makes sense economically when dealing with surge capacities.

Customer service is another area that third-party logistics can improve. A third-party provider can make more frequent deliveries to the customer, and one that has multiple distribution centers may also be able to reduce the lead times by being located closer to the customer. Having multiple distribution locations is a big advantage of using third party providers.

Today, the nature of the global economy dictates that companies must continue to search for overseas markets. The challenge with this growth is that many companies do not have distribution networks in foreign countries, and customer service will suffer if all products are distributed from the home country. Third-party providers can aid in overseas distribution and provide good customer service in the process. This is especially true when a company enters a new marketplace. In this situation, the third-party provider who is already established there can smooth a company's entry.

Another third party opportunity is in asset utilization. Because they operate on a large scale, third-party logistics providers can maximize the utilization of their trucking fleet and spread the overhead cost over many customers. Because of the scale of their operations, third-party providers can sometimes invest in efficient picking technologies that may or may not be justifiable in a small scale operation.

Third parties can also provide benefits in shipment consolidation, since they generally have multiple customers. The greater shipping volume increases the opportunities for consolidation. Also, because of the greater number of shipping points, the third-party provider can reduce the total travel distances, resulting in further transportation cost savings.

Information Technology

The third logistics front is information technology. Solutions that are being developed now and that will be developed in the future rely on information technology to improve operations. The proper use of information technology spans all of the logistics fronts; without an integrated approach to this technology, the other logistics fronts cannot be worked effectively.

The first information technology opportunity is distribution requirements planning (DRP). DRP is a global planning tool to manage the total logistics pipeline; it brings a closer integration of

the complete logistics network and will drive savings through the total network. DRP aids in planning transportation costs, warehousing requirements, inventory quantities, and positions. Because it is global by nature, DRP will provide a company with a global measurement of distribution.

Global measurement in distribution allows companies to centralize the buying and planning process, giving them greater control over their inventory and presenting additional inventory opportunities. A properly implemented DRP system will allow increased inventory turns, permit quicker responses to market changes, support JIT replenishment, shrink obsolescence, and anticipate and minimize future inventory problems.

The second information technology opportunity is electronic data interchange (EDI), the electronic transfer of documents from one computer system to another. EDI takes externally produced and transmitted information and allows that information to be electronically received into the host system. Then, the host system is able to electronically send information to another external computer system. Because the transaction is free from human intervention, EDI provides a high level of accuracy for the information being received and transmitted.

Companies that wish to improve their logistics operations must invest in EDI technologies. There are several factors driving EDI's growth. At the top of the list is that most retail trading partners now require EDI transactions. As a minimum requirement for doing business with a retailer, most trading partners must be capable of providing an advanced shipping notice (ASN). This document is in addition to the many documents usually required by retailers. Without the ability to provide electronic documents, a company may lose business or pay stiff compliance penalties until it has EDI capabilities.

An associated benefit with EDI is that it allows a company to more closely integrate itself with its trading partners. As one of the foundation tools for a successful partnership, EDI is required if two companies are to become closely integrated and aligned with the same logistics goals. The second associated benefit with EDI is that it reduces information lead times and thus allows the logistics network to be more responsive to customer needs and changing market conditions. It also reduces the transportation and order processing lead times.

The third information technology opportunity is the utilization of Warehouse Management Systems (WMS), software packages used to meet the two objectives of warehousing: to maximize the use of space, equipment, and labor and to exceed customer expectations. The WMS accomplishes this by directing labor and providing inventory and location expectations.

The use of a WMS provides many logistics benefits, among them reducing warehouse operating costs by improving labor productivity and operating in real-time mode. The WMS reduces the travel times associated with performing a task or series of tasks, resulting in increased worker productivity. For example, a WMS will reduce hunt and search times as a result of high levels of inventory. By creating an environment that approaches 100% information accuracy, the WMS allows for the elimination of many non-value-added steps. Through real-time operation, a WMS can support a reduction in lead times for both order processing and inventory management. These benefits can in turn support better customer service and a quicker turn on inventory, both of which will provide financial savings in warehousing operations.

The fourth information technology opportunity is in the utilization of transportation management systems (TMS). A transportation management system provides five basic functions:

- Planning
- Carrier Performance
- Trailer Loading
- Highway Mileage Freight Payment Auditing
- Transportation

When automated, these functions provide significant opportunities for improvement and allow the transportation department to manage rather than react to transportation events and opportunities. Today, transportation management is a relationship-based business. The transportation department spends the vast majority of its time answering questions, performing administrative tasks, reviewing freight bills, and managing the carrier relationship. TMS technology alleviates many of the administrative tasks through automation. As a result, the transportation department is now free to focus on transportation planning.

The fifth opportunity is in order processing. The nature of the pull system and the need to improve the logistics network have both required that companies process orders more quickly. Batch order processing systems are being replaced with real-time systems to speed order filling. As a result, companies that can process orders real-time or same-day are gaining a competitive advantage. The challenges with real-time order processing are to make sure the existing computer systems can support the operation and that the physical distribution system can handle small order processing windows.

The sixth opportunity is in electronic purchasing. Manual purchasing methods generate significant volumes of paper, thus introducing multiple opportunities for error and adding lead time to the logistics process. Electronic purchasing allows for a more seamless exchange of information between trading partners and reduces the amount of time associated with purchasing. This reduction in time will result in a total inventory reduction.

The seventh opportunity is automatic identification (Auto ID) technologies, which encompass all of the technologies associated with printing and reading the bar code, including the printer technology and radio frequency (RF) equipment. The use of these automatic identification technologies will support the highest levels of information accuracy.

The key to understanding Auto ID technology is to realize that it is an information accuracy enabler, allowing information to be accurately transmitted at all steps in the process. The need to accommodate real-time exchange of information is accomplished through real-time systems. The need for this information to be 100% accurate is accomplished through Auto ID.

Bar coding in logistics allows information to be quickly and accurately processed internally and externally. Accuracy and timeliness further contribute to reducing the amount of time a product spends in the pipeline. This high level of accuracy also aids in the reduction of non-valued-added processes associated with inaccurate information.

Transportation

The relationships between the transportation department and various carriers have traditionally dictated who will get the bulk of the transportation business. Management of a high number of carries has typically been at the center of the transportation function, in order to ensure getting what seemed like the most competitive price. However, this situation is not always beneficial for everyone involved. Often there is usually no volume commitment and no discount for continuous moves.

Because transportation is a function that requires a win/win environment, quality transportation is one of the key requirements to a successful logistics program. The relationship must move from carrier management to partnership and planning if a company is to be successful in its logistics efforts.

A key opportunity is in planning, which must be one of the focal points of the transportation department. Very little time is spent in most organizations on the planning function. Most transportation departments spend their time in administration and answering questions.

Other opportunities in transportation include fleet management, breakbulk, load consolidation, responsiveness, and back hauls.

Warehousing

The warehouse plays a critical role in supporting a company's logistics efforts. If the warehouse cannot process orders quickly, effectively, and accurately, then logistics efforts will suffer. Information technology plays a significant role in making warehousing operations more effective, but the best information system will be of little use if the physical systems necessary to get the products out the door are constraining, misapplied, or outdated. All of the warehousing logistics opportunities discussed below will allow the warehouse to more effectively process and ship orders.

The first warehousing logistics opportunity is in improving order picking operations. Traditionally, order picking is the operation where a company spends or misspends most of its time and money to improve productivity. Successful order picking is critical to a warehouse's success, and logistics trends today are driving warehousing operations to develop better order picking solutions.

Another current trend in the warehousing industry involves using more SKUs and more frequent order delivery—all part of the quest to provide superior customer service. By allowing customers to order more frequently and by providing them with greater variety, the warehouse encourages smaller orders and fewer units per line. In turn, this results in more total lines picked in the warehouse. Larger volumes encourage a customer to increase the variety of products that they order, which results in more lines per order. As a result, the warehouse picks more line items per unit.

A second trend in warehousing is presorting or prelabeling selected orders, which further complicates order picking by adding additional steps to the process. The warehouse must now perform some of the activities that might have been performed in the customer's warehouse. This trend is likely to continue, as it will streamline the receiving process and support crossdocking opportunities in the customer's distribution center.

Both of these trends require that the order picking process be carefully designed and improved to support timely processing. In many cases, companies must improve their order picking operations to stay even in the productivity race. This is leading to more investments in conveyors, automated material handling, and storage solutions. In many cases, the investment in automation is being made to increase the flow-through capacity of the warehouse and not necessarily to reduce labor costs or improve productivity. If the product cannot get out the door in a timely manner, there will be no need to worry about order picking; there will be no orders.

The second warehousing opportunity is in crossdocking. Crossdocking can occur at the level of the manufacturer, distributor, retailer, and/or transportation carrier. Each participant has different requirements depending on whether they are shipping the goods to be crossdocked or preparing to receive crossdocked goods. The receiver typically requests that the crossdocked goods be sorted and prelabeled. To meet these requirements, the shipper must perform a more detailed picking process. For example, if 100 items are ordered, the warehouse must pick the 100 items and also separate those items for the different store orders.

The first benefit of using crossdocking is that it speeds up the receiving process, allowing the receiving warehouse to flow the inbound product more quickly and thus reduce turnaround times. The product comes in prelabeled and presorted, and the receiving warehouse does not have to prepare the product for outbound shipment. Another benefit of crossdocking is that it can reduce the amount of material handling in the receiving warehouse. Here, product is not stored, but merely moved across the staging area. This will reduce both storage requirements and the total time spent moving product into and out of the storage area.

The third warehousing opportunity is in productivity. In the past, productivity has meant doing it faster with fewer people. The first objective of warehousing has always been to maximize the effective use of space, equipment, and labor. This objective implies that productivity is not just labor performance but also includes space and equipment and a combination of factors that all contribute to increased productivity.

Logistics opportunities exist both in understanding productivity and in being able to effectively measure it. Productivity is not merely how many cases per hour a person can pick or receive. Rather, productivity is a measure of how many cases per hour a person receives, how quickly that information is entered into the system, how accurate the receiving process is, and what is done with this information. Because productivity information can be collected through a company's information system, it is possible to create a more realistic picture of total productivity. Once this information is understood, it is possible to better meet warehousing objectives.

The fourth warehousing opportunity is in space utilization. The old rule of thumb has always been that when a warehouse is more than 80% full, more space is needed. This rule is based on the fact that it takes longer to put something away at 80% capacity. As the time to find a storage location increases, proper slotting of product starts to disappear. Slow-moving items are stored in fast-moving locations, and fast-moving items must be stored in slow-moving locations. The end result is a decline in productivity and an increase in damage and mispicks, all due to poor space utilization. By tracking space utilization, management is able to anticipate when the warehouse will become too full and understand the impact space has on labor productivity.

The fifth warehousing opportunity is in value-added services. Warehouses are no longer just picking and shipping locations. Instead, their role has extended to include services that facilitate more efficient operations in the receiving warehouse and therefore benefit the customer. Whether it is presorting and prelabeling goods for eventual crossdocking or the actual customization of the outbound product, the demands brought by customers are becoming more strenuous.

As a result, provision of value-added services is quickly becoming a logistics requirement. Specific value-added services being provided today include pre-ticketing and marking for retailers, small assembly operations, customer-specific packaging, and customer presorting. The list goes on and on. An activity is a candidate for being a value-added service if, in performing that activity, the vendor will save time in the customer's receiving, putaway, picking, or shipping operation.

Providers must avoid a situation where the value-added service is merely a shift of costs without proper compensation for the vendor providing the service. Providing value-added services must be a win/win situation. Of course, this is not always the case. In some instances, a value-added service becomes a requirement for doing business with a specific customer. In that case, other productivity savings must be uncovered in the warehouse to support the increased costs.

The benefit of providing value-added services to your customer is that these services will help you develop a stronger partnership. Your customer will rely on you to provide these services, resulting in long-term relationships that can only benefit your business.

Conclusion

Logistics excellence can only be achieved through an understanding all of the logistics fronts in: distribution, third-party logistics, information technology, transportation, and warehousing. With a complete understanding of these fronts, companies can use them together to meet customer service needs, reduce costs, increase operation efficiency, and improve implementation of new technology.

Logistics in the New Millennium

Dan Harrison

Logistics in the new millennium will be far more precise than now and much more customer-oriented, said speakers at a recent meeting of perishable logistics professionals.

"We're beginning to live in the information age," said Prof. Donald J. Bowersox of Michigan State University. "For example, we used to talk about estimated times of arrival, but now there are tracking systems that can tell within seconds the actual time of arrival."

"Win/win" used to not be part of the vocabulary, Bowersox told the meeting, in no small part because channel structures, primarily by their design, are adversarial as opposed to cooperative in nature. "There are few courses in cooperation instead of competition," he noted. But in today's world, with cooperative arrangements, "we're suddenly beginning to realize we have opportunities to share risks and gains, and the whole notion of relationship management is changing the way we think about our business."

"This has spawned a logistical renaissance," Bowersox said. "Years ago, the word 'logistics' was reserved for the military. Nobody in business talked about it. But one of the hottest topics in business today is the logistics of business, and there's a lot we know about it. One thing we know is we've seen more change in logistics best practices in the past 10 years than in all the decades before that since the Industrial Revolution."

Bowersox noted that in 1980, when transportation was deregulated, logistics accounted for 17% of the [US] gross domestic product, with transportation 44% of logistics costs. By the end of 1996, logistics had dropped to 10.8% of GDP, but transportation had risen to 57% of all logistics costs. "There's no such thing as cheap transportation, and precise transportation can exploit other advantages and lower the costs of all other logistics through less warehousing, handling, inventory, in-and-out movement, redundancy, and waste."

That transportation can serve logistical efficiencies is a sign of a breakthrough in the importance of logistics, Bowersox told the meeting.

In the new millennium, he continued, time-based competition will drive much business activity, "learning to accomplish more and more with less and less, until you are achieving everything using nothing. People want to grow their businesses with fewer buildings and facilities, less cubic feet, smaller fleets with bigger trailers, and the like."

Time-based competition, Bowersox said, is all about understanding that the technology exists that allows people to focus on the process, as opposed to the function, and to understand better how overall perishable support can be integrated.

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For years, he noted, people in the logistics business were satisfied to talk about one level of performance. When the system worked perfectly, he said, a 95% fill rate meant that one would "screw up 5% of the time by design." But that thinking is gone, Bowersox contended, with "technology finally driving us to realize we can't just implant technology in our old processes and expect things to get better. If we don't change the fundamental way we work to take advantage of the technology, we will always at best have incremental or small gains when we install new technology."

Bowersox said some people are beginning to get out of the box and think of totally new ways to let technology drive time-based management so risk and assets committed across the supply chain can be lowered. "We're learning that speed alone isn't a major attribute," he said. "How many times have you experienced arrival of an expedited truck, only for it to be positioned in the yard and not loaded? Or you have no record of something already in the yard, or inventory is received but not in your records?

"The game is about synchronization, trying to put together carriers, third-party logistics companies, receivers, and shippers, so we don't idle merchandise on its way to market or when it doesn't have to be. You want to eliminate causing merchandise to be rehandled or diverted and reconsigned, shipped away, and brought back to the frozen food warehouse because there wasn't space to bring it in, causing temporary storage."

Only with a vision of total supply chain control, where every piece of work is assessed to see if it adds value, can industry begin to work on ways to eliminate redundancies, Bowersox said. He called this a tough challenge.

Too many people haven't changed the way they do much of their work to take advantage of technological capabilities, Bowersox asserted. "People are locked into mindsets, with standard operating procedures, and most of their vision doesn't expand beyond their own corporation. They don't see the whole set of supply chain relationships. When they try to solve things, it's by trying to figure out a way to do things faster. But that creates 'hurry up and wait,' because they don't get synchronization properly in place."

Bowersox expressed concern that many big companies are not doing a complete job as they move toward enterprise resource planning systems that they hope will create the ability to synchronize with supply chain partners. "The problem is that, at the next level down, the operating aspects of those systems are not very well integrated. Therefore, their ability to house legacy systems by good warehouse management and good transportation routing software is very minimal."

Nonetheless, Bowersox forecasted a shift away from the traditional anticipatory chain of distribution to a more response-based chain. He noted that the anticipatory chain has been forecast-driven, but that the ability to forecast events across the supply chain isn't very good. "The history, no matter how sophisticated, doesn't seem to come down to a level of accuracy to really plan systems. Occasionally, some DSD or direct plant delivery will be introduced to deal with a specific known event, but for the most part it's stock the inventory in anticipation of future sales."

But there are the beginnings of a shift to more response-based, "multiplex" distribution arrangements, Bowersox said. "People are beginning to put together the right solution for each problem and are not locked into one way of doing things. No one mentality drives the total system all the time, and if we can begin to share information across the supply chain, opening information

channels between systems and responding to what customers want, not to what we think they want, there will be tremendous change."

Another speaker, C. James Pierce, vice president of program development at AmeriCold Logistics, observed that demand and product flow often aren't really coordinated. As a result, he noted, there can be the wrong product at the wrong place at the wrong time, and transportation costs can rise substantially because product has to be moved around.

Fill rates may have had a 95% comfort level before, Pierce told the meeting, "but that now makes you a non-player." In the future, he said, there will be an integrated grocery demand chain. "Rather than being a traditional supply chain, what will count is really what consumer demand is all about. There will be continuous paperless information flow, with information moving faster than it's ever moved before from the consumer back through the supply chain. But the focus won't be on supply but demand, with the consumer being king."

Pierce spoke of the prospect of so-called virtual companies, noting that even manufacturing can be outsourced if a company truly wants to be a brand company rather than a manufacturing company. Therefore, logistics could be outsourced. At the retail level, DSD could mean retailers could have just one level of high fixed expense, a store, but even that could be somewhat of a virtual store, thanks to the Internet.

A focus on ever-changing consumer demand will reduce inventories, Pierce said, because there will be far fewer places for inventory to come to rest. The final form of a product could be delayed as much as possible, until just before the consumer demands it. This could be bright stock, where packaging is decided closer to when product is ordered, or bulk product measured out in exact quantities the consumer wants, or whatever might fit in with consumer demand.

This type of activity would obviously reduce inventory, because there would be fewer finished foods necessary to fill the pipeline until just before consumer demand, Pierce said. He cited an Andersen Consulting study that said if this type of supply chain is ever implemented, total logistics costs would be reduced as much as 40% and total days in the system as much as 70%. "It remains to be seen what adapting to changes in the demand chain will mean to all components of the supply chain," Pierce said.

He cited several forces shaping the demand chain, including consumer demands, globalization, and information management.

On consumer demands, Pierce said they want what they want when they want it, "and, by the way, it had better be cheap." They could price compare via the Internet, which is quicker and more convenient, and therefore a challenge to traditional suppliers. "They're also moving from buying a product to buying a bundled solution, not just a product but a group of products, no longer just a good, but a good and a service." Delivery will often be direct to the consumption point, rather than into a store, Pierce predicted, adding that in the next 10 years, there will be a whole new wave of "household replenishment service providers."

Globalization will mean greater supply/demand chain flexibility due to changing world demographics, Pierce said. Competitors can come from anywhere in the world, not just North America, if they have the right tools and technologies.

As for information management, Pierce said as much as half or more of business transactions in the next 10 years will be on the Internet.

Industrial Truck Operator Training

Steve Alberda

Background

Each year in the United States, nearly 100 workers are killed and another 20,000 are seriously injured in forklift-related incidents. Overturns are the leading cause of fatalities representing about 25% of all forklift-related deaths. Many employees are injured when lift trucks are inadvertently driven off loading docks or they fall between docks and an unsecured trailer. Pedestrians are also struck by a lift truck or employees fall while on elevated pallets. Many incidents also involve property damage, including damage to overhead sprinklers, product storage racks, pipes, walls, and machinery. Many of these injuries and much of the property damage can be attributed to lack of safe operating procedures, enforcement of the rules, or inadequate training.

Prior to 1999, OSHA's Powered Industrial Truck standard employees to be trained to operate a powered industrial truck; however, the OSHA standard did not stipulate the training requirements. Due to the frequency and severity of these injuries, in March of 1999, OSHA revised the Powered Industrial Truck standard (CFR 1910.178). The new standard is performance based, meaning that it stipulates minimum training requirements and requires employers to insure that operators must receive required training and prove that PIT operators are competent by passing both a written and practical test. Employers are not required to duplicate training if the operator has been evaluated and found to be competent.

General Training Requirements

The OSHA regulation states that "Only trained and authorized operators shall be permitted to operate a powered industrial truck". It is up to the employer to provide operators with training that helps them obtain the knowledge and skills to operate a PIT in a safe, efficient manner.

PIT training must consist of a combination of formal instruction and practical training. Formal instruction can take many forms. It may consist of lecture, discussion, written materials, videos or interactive computer training. On the other hand, practical training must only be made up of demonstrations by the instructor and exercises performed by the trainee. It is important to note that trainees may only operate a powered industrial truck under the direct supervision of a trainer and where the operation of the vehicle does not endanger the trainee or co-workers. Training must only be done by a trainer with knowledge, skills and experience.

Employers must certify that operators have been trained and evaluated. Certification means that the trainer is in some way confirming or validating that the operator was trained. As a result, employers need to have written documentation that shows that employees passed a written exam and a practical driving test. At minimum, OSHA requires the documentation to include the name of the operator, date of evaluation and the identity of the trainer. Many employers like a license to operators. I strongly recommend backing up the license with a database in case you need to prove that the operator is certified and the operator has forgotten his / her license.

This database also can be used to determine when operators are due for re-certification and can contain other pertinent information such as what vehicles they're certified to operate, re-training, etc.

Training Requirements

The Powered Industrial Truck standard requires employers to provide employees with training on at least twenty topics related to the operation of powered industrial trucks. These training requirements can be put into one of two categories: truck-related or workplace-related. Truck-related training refers to the things that operators will need to know to safely operate their lift truck such as the function and operation of the gauges, controls and switches, pinch points, seatbelts, etc. Workplace-related training refers to the things that your operators will need to know to safely operate the vehicle in your workplace such as ramps, hazardous locations, pedestrian traffic, etc.

Operating Instructions

Because there are many different types of powered industrial trucks, employers need to provide training on the operating instructions for all PIT's that employees are assigned to operate. Employees need to learn the location, function and operation of all gauges, controls and switches. The best place to go for this information is the operator's manual. At minimum, instructors should cover all information that is relevant to their operation.

General Safety Concerns

Employers are required to provide operators with general lift truck safety information that pertains to all powered industrial trucks. For instance, overturns are the leading cause of deaths associated with powered industrial trucks. Operators need to be trained that if their vehicle is tipping they are safest if they wear their seatbelt and stay inside the cage of the lift. Most deaths occur when a lift truck tips and someone tries to jump free of the lift and doesn't jump far enough and is crushed to death. Operators should be told that if their truck starts to tip over to stay in your seat, and go with the truck, grip the wheel securely and brace yourself with your feet. Some other general safety concerns are:

- Looking in the path of travel
- Stopping and looking before changing direction
- Walking under raised forks
- Driving around pedestrians with an elevated load
- Lifting personnel without the proper attachments
- Pedestrian safety
- Keeping body parts inside the running lines of the truck
- Pinch points
- Seatbelts
- Intersections
- Your facility's operating rules

Differences Between the Powered Industrial Truck and the Automobile

Inexperienced operators often come with the idea that if they can operate a car, they can operate a powered industrial truck. The reality is that the similarity between powered industrial trucks

and an automobile may be that they both have an accelerator, brakes, steering wheel and a horn. In fact, sometimes those similarities don't apply. This is why employers are required to inform operators of the difference between powered industrial trucks and the automobile.

For example, powered industrial trucks are counterbalanced and designed to carry heavy loads with a driver and no passengers. On the other hand, an automobile is designed to carry more than one person, but is not designed to move heavy loads. Another example is that forklifts have rear wheel steering while automobiles are steered with the front wheel, allowing forklifts and reach trucks to have a very tight turning radius. Some other differences between the powered industrial truck and the automobile are, controls and fuels just to name a few.

Controls

Employers are required to train employees how to operate the controls of all powered industrial trucks they are assigned to operate. Even if an employee knows how to operate one make or model of forklift, they may not know how that controls operate on that vehicle. Similarly, it is important to teach employees how to operate the controls of each type / model of vehicle they may be assigned to operate.

All powered industrial trucks are equipped with a directional control which allows the operator to move the truck forward or backward. All powered industrial trucks have some sort of accelerator and brake although how they are applied may be very different. For instance, to apply the brake on a walker-rider, the operator can plug the machine or pull back on the steering handle. On a reach truck, the operator has to take his foot off the pedal while on a forklift the brake pedal needs to be depressed. In addition to these examples, operators need to know how to operate the parking brake, clutch, lift controls, tilt controls, etc. Be sure that your training material covers how to operate all of the controls.

Switches

Employers must also teach operators how to operate all switches. Like the controls the way switches operate can vary from vehicle to vehicle. Operators need to be taught how to use the horn, ignition, lights and signal for all vehicles they are assigned to operate.

Steering and Maneuvering

There are similarities and differences between the operation of a powered industrial truck and a car. New operators begin driving a powered industrial truck and immediately notice that, as with a car, when the turn the wheel to the right, it causes the PIT to turn right. What new and inexperienced operators fail to realize is that the similarities end there. A powered industrial truck has rear wheel steering which allows it to turn in a tighter circle than most vehicles.

Trainees also don't always realize how much the load that they are transporting affects the stability of the vehicle. They need to be taught that the higher they lift a load, the more unstable it becomes. Trainees need to learn that when transporting loads, they should never raise their load more than 8 inches from the ground and it must be tilted back.

It is critical that all trainees learn about the hazards of turning with an elevated load. The higher a load is raised, he less stable it is. That is why trainees need to be informed that if it is necessary to move the lift truck with a raised load, such as when they are right angle stacking, they need to

slow down, turn only as much as necessary and then lower their load and complete the turn.

Trainees must also watch for overhead obstructions such as refrigeration equipment, pipes, signs and beams. They not only need to be aware of their path of travel at floor level, but also above where they could strike overhead equipment or stored product.

Visibility

Lift trucks are designed to carry loads with the load carried on the forks at the front of the vehicle. Operators must be taught that when loads are carried on the forks in the front of the vehicle, they may obscure the operator's forward vision. In the absence of company rules, operators need to drive in reverse if the load may prevent them from seeing the path of travel.

Forks and Attachments

Attachments affect the operation of a powered industrial truck. Operators need to know how the attachment operates and how it is controlled. It is also advisable for operators to understand how the attachment is used in the operation, the limitations of its use and any hazards associated with using the attachment. An operator must take the weight of the attachments into account and considering its weight as part of the load. Failure to account for the added weight of attachments can lead to a tip-over. Employers need to consult the operator's manual for this information and train operators accordingly.

Data Plates

The data plate is one of the most important, yet over-looked, components of all vehicles. All industrial trucks must have a data plate attached to the truck body. The information on the data plate must be legible.

Data plates display important information concerning the type of the truck, the capacity and load center and the weight of the truck. Operator training must include how to read and use the information on the data.

Stability Triangle

Operators must understand the concept of the stability triangle. Operators must understand the concept stability triangle to know that a lift truck will not tip over as long as the center of gravity remains inside the triangle. Similarly, operators need to know about forces that cause tip-over. For instance, they need to be taught that if the center of gravity shifts outside the stability triangle, the lift truck will tip over. Likewise, it is critical for operators to understand that they control the tip-over by insuring that the center of gravity is inside the stability triangle. Operators can control the center of gravity within a lift truck and can move it by:

- Traveling with an elevated load
- Trying to carry too heavy a load
- Trying to turn the lift truck while it is moving too fast
- Operating the lift truck on a hill or incline
- Starting or stopping too fast
- Jerky operation of the hydraulic system

Operators also need to know understand how truck measurements affect stability of the lift truck. The front wheels of a lift truck serve as the fulcrum point between the weight of the truck and the weight of the load being carried. If the weight of the load is equal to the weight of the truck, with equal distances between the centers of gravity, it is possible to "seesaw" a lift truck on its front wheels. If the load is rearranged so the load center is farther away from the fulcrum point, it will cause the center of gravity for both the truck and the load to shift beyond the front wheels of the truck, and the truck will tip forward. If, on the other hand, the load is arranged so the center of gravity is closer to the fulcrum point, it will cause the center of gravity for both the truck and the load to shift behind the front wheels of the truck. With this arrangement, there is no danger of the truck tipping forward.

Vehicle Inspection and Maintenance

Pre-operational vehicle inspections are required. Operators need to understand that it is their responsibility to conduct a pre-operational inspection and to complete an inspection report. The report is used to record equipment problems and get them fixed. It is important to explain the reason a pre-operational vehicle inspection is required, how to conduct the inspection, what to do a defect is found and your policy and reporting procedures.

Operators should begin the pre-operational inspection by checking the safety equipment on their lift truck such as the seatbelt, warning lights, backup alarm and horn. At minimum, they should also check the following:

- **Steering**–Check steering for free play. Should not be more than 1 – 2 inches either way.
- **Brakes**–Brakes should depress smoothly and should not require excessive force to operate. When pressing the brakes, the pedal should not sink under continued pressure. When you drive your lift truck, the brakes should not grab or cause the truck to swerve. Brakes that make a grinding or screeching noise need immediate attention. The parking brake should also be checked at this time.
- **Upright**–Look for any broken, chipped, misaligned, warped or worn parts in the chains, hydraulic cylinder, mast/upright or forks.
- **Hydraulic Hoses**–Visually examine the hydraulic hoses and connections to be sure the hoses are in good condition. Check for leaks around fittings and connecting points.
- **Hydraulic Controls**–Control levers should move smoothly and return to neutral when released. Feel for roughness in the action when the forks are raised or tilted. No slipping or moving of the forks or mast should occur when they are moved to a new position.
- **Tires and Wheels**–Visually inspect the tires. Look for damage, wear, missing bolts, or other signs that a tire is not in good condition. From time to time, check the air pressure in pneumatic tires. Always use a long tire gauge and face the tread, not the side of the tire, when checking tire pressure.
- **Hour Meter**–During the inspection, note the engine hour meter to note when scheduled maintenance is needed
- **Leaks**–Look for leaks. Brake fluid, transmission oil, radiator coolant, battery acid (electro-

lyte), or fuel can leak from your lift truck. Operators should be taught not to drive a forklift with a leak.

- **Levels**–Check fuel level on LP gas or gasoline trucks. Also, the oil level and pressure, water level, and fan belt.

- **Battery**–If the operator drives a battery powered lift truck, check the battery plug connection, battery charge, and load test the battery.

Refueling

Operators must be taught the potential hazards of refueling or changing and charging batteries. When refueling, they need to park their lift truck in a designated refueling / recharging area making sure not to not block doorways or access to production or emergency equipment. They also need to make sure that the area is well ventilated to avoid buildup of hazardous gasses. They need to check to see that there is a fire extinguisher nearby in case of a fire. Before replacing an LP gas tank they need to close the shut off valve and let the engine run until it stall to reduce the risk of releasing fuel vapors. They need to turn off the engine and any lights to avoid running down the charging system. Operators also need to check for damage to connections and look for leaks.

When recharging, the battery must be recharged in a well ventilated area to avoid buildup of hydrogen gasses. Electrical arcing will ignite hydrogen gas. It is important to keep tools and other metal objects away from the top of uncovered batteries. It is also important that metal jewelry such as rings and watches, when struck against another metal object, can ignite battery gasses. Operators should be advised not to wear metal jewelry, or to cover metal jewelry, in these cases.

Operators must also take care not to spill any battery acid (electrolyte). If they do, it needs to be cleaned up using an absorbent material such as baking soda to neutralize the battery acid. Batteries, when they are recharging, produce heat, so the battery compartment lid must be kept open. All prescribed safety equipment (face shield, rubber gloves, rubber apron, etc.) must be worn to avoid contact with battery acid. Operators must also be cautioned never to rub their eyes or skin unless their PPE is removed and their hands are washed.

Battery Changing and Charging

Forklift Batteries

There are several types of batteries in industrial trucks today including lead-acid and nickel-iron. Both of these batteries pose a health threat in several ways....

- Shear weight—some batteries weigh as much as 2000 lbs. or more
- Gases emitted during charging can be highly volatile
- Corrosive chemicals within the battery

For these reasons, battery charging stations and the employees that work around them must be properly equipped and certain safety procedures implemented.

To protect workers from danger associated with the battery's weight, the batteries should only

be removed and replaced from the forklifts using an appropriately equipped forklift or battery cart specifically designed for transporting batteries.

Batteries that are being removed or replaced should be securely placed and restrained in the cart or the forklift. Operators must use the correct tools and follow proper procedures when moving batteries. This will ensure that the battery does not fall.

Batteries release oxygen and hydrogen gases when they are charging. This effect, called "out gassing" is more noticeable if the battery is being overcharged. In the right concentrations, these gases can be highly explosive. Due to this "out gassing" effect, charging stations should be located in well-ventilated areas, to prevent concentrations of hydrogen and oxygen from reaching volatile levels. General or local ventilation can be provided by a fume hood or an exhaust fan. If an on-board charging system is used, the industrial truck itself should be parked in a location where there is adequate ventilation.

Sulfuric acid is a common and hazardous component in a battery. In the event of a battery acid spill, neutralizing agents should be spread on the spill. These cleanup materials should be on hand at all times. After the spill is neutralized, it can be safely cleaned up and disposed of in accordance with local ordinances. Only properly trained and authorized employees should perform an acid cleanup.

Personal Protective Equipment (PPE)

Whenever changing or servicing a battery, personal protective equipment (PPE) should be worn to prevent harm if an accident should occur. The first area of concern is the weight of the battery. To protect workers against drops, proper footwear like steel-toe boots or foot guards should be worn.

Maintaining batteries by adding water or acid also requires appropriate protection. Chemical-resistant gloves, acid apron, eyewear and face protection are a must. They will reduce the risk of injury should an acid splash occur. Protective eye and face equipment must be avail-able where there is a good chance that injuries could be prevented by using such equipment. In the United States, face protection must meet the ANSI Z87.1-1989 specifications or be proven equally effective. Face shields are considered as secondary eye protection only. Indirect or non-vented safety goggles must also be worn to protect the eyes.

An eye/face wash and shower are other required pieces of equipment that must be in or near a battery changing area. Emergency showers / eyewash stations must be within 10 seconds in distance of the hazard and on the same level as that hazard. This unit needs to be clearly identified with proper signs and adequate lighting.

Operating Limitations

Lift truck operators must also be taught how operating limitations affect the safe operation of a lift truck. Operators may encounter a variety of potential hazards depending on the operating environment. Following are several operating environments that must be discussed with operators:

Surface Conditions Encountered

A variety of surface conditions can damage a lift truck or cause an accident. Operators should

learn to avoid rough spots and pot holes and other potentially unsafe surfaces. If an operator is required to drive on surfaces such as ice, mud, gravel, sand, and soft dirt, they need to know the potential hazards and how to avoid them. Similarly, if the operator cannot avoid a rough spot such as railroad tracks, they should be taught to slow down and cross it carefully, at an angle, one wheel at a time.

Load composition and stability

Similarly, load composition can affect the stability of the load and the vehicle. Operators should learn that when lifting and carrying several loads at once, they need to place the heaviest load against the back of the forks. Placing the heaviest loads near the back of the forks shifts the load center closer to the front wheels and makes for a more stable load. You can increase the stability of a load by tilting the forks back. Tilting the forks back moves the load center closer to the front wheels. On the other hand, tilting the forks forward shifts the load center away from the front wheels and creates a less stable load, especially when the forks are raised. Operators should learn never to tilt the forks forward when they are raised, except to deposit a load.

Load Manipulation, Stacking and Unstacking

There are times when an operator needs to move a lift truck with a raised load. An example would be when the operator is required to perform right angle stacking. In a situation such as this, the operator needs to learn to slow down keeping in mind that the higher they raise the load, the less stable it is.

Operators must also consider overhead clearance. As the operator lifts and transports loads, they need to realize the importance of watching for overhead obstructions.

Loads must also be centered. Operators need to take time to adjust the forks to fit the load they are carrying. Adjusting the forks outward for wide loads, helps to center the load, and make it more stable.

Operators must learn never try to lift or carry loose or poorly stacked loads. They need to learn to correctly stack and secure loads to prevent an accident that could damage the load, the lift truck, pedestrians or themselves.

Wide and long loads are more unstable than other loads. Wide loads require that the operator keep them low, watching the balance of the load. Similarly, when lifting and carrying long loads, the operator needs to keep in mind the load center and lift capacity of the lift truck. With both wide and long loads, the lift truck operator needs more room to maneuver. In a situation like this, operators need to learn to slow down and watch their clearance.

Sloped Surfaces and How They Affect Stability

If operators need to driver on ramps and inclines, they need to understand how it can affect the stability of the lift truck. If they are driving an empty truck, they must travel in reverse up an incline or forward down an incline because the center of gravity is above the front drive wheels. If, on the other hand, the operator is driving a loaded truck, they need to travel forward up an incline, and backward down an incline with the center of gravity for the load above the front drive wheels. Operators must learn never to turn while driving up or down a ramp or incline or drive diagonally across a ramp or incline because lift trucks are narrow, the center of gravity can

quickly shift outside the stability triangle, causing the truck to tip over.

Load Composition and Stability

Operators must be taught that when lifting and carrying several loads at once, they must always place the heaviest load against the back of the forks. Placing the heaviest loads near the back of the forks shifts the load center closer to the front wheels and makes for a more stable load. Operators can increase the stability of a load by tilting the forks back. Tilting the forks back moves the load center closer to the front wheels. On the other hand, tilting the forks forward shifts the load center away from the front wheels and creates a less stable load, especially when the forks are raised. Operators should be cautioned against tilting the forks forward when they are raised, except to deposit a load.

Other Potential Operating Limitations

There are also other potential operating limitations of which operators must be trained depending on the facility. Operators need to be aware of the maximum weight capacity of elevators before using them. Operators need to be taught to calculate the total weight of the lift truck and their load before entering the elevator.

Loading docks can also be hazardous. Operators must be aware of the edge of the dock because a fall from a loading dock in a lift truck can be fatal. When operators load or unload a trailer they need to inspect the floor of the trailer to ensure that it will support the lift truck and the load, insure that the trailer is restrained or the wheels are chocked to prevent the trailer from moving and to make sure that dock plates, boards, and ramps are in place and secure.

Closing Remarks

As an employer, your training program is an important investment in your employees that will pay dividends later. Well trained lift truck operators are the life blood of a warehouse. A well trained operator is more efficient, safe and is less likely to damage product, structures or equipment. I encourage you to invest adequate training.

Is your training program a recipe for success or failure? As with any recipe, your final product will only be as good as the ingredients and the "cook".

FOOD SAFETY ISSUES

Food safety may be defined as the assurance that food will not cause harm to the consumer when it is prepared or eaten according to its intended use. (FAO/WHO, 1997). This guarantee means reducing risks that may result from the production and handling of produce.

Public concern about food safety has increased dramatically in the last years as a result of food-borne diseases. The World Health Organization (WHO, 1999) estimates large populations of people suffering from diseases resulting from contaminated food or water. Incidence of food borne diseases can be 300 to 350 times higher than that actually reported worldwide. Risks associated to chemical contaminated foods, such as pesticide residues, although less dramatic and immediate in their outcome, are a permanent concern for customers.

The value chain for fresh fruits and vegetables has several links: production, harvesting, post-harvest treatments, packaging, transport and storage, each with its own contamination hazards, depending on size of operations, of production and of processing systems in use. Considering the diversity of activities and risks associated to food production and in particular for fruits and vegetables to be consumed fresh, it is important to implement safety assurance programs addressed both to the internal and export markets.

Application of fresh fruits and vegetables safety assurance programs include awareness about Good Agricultural Practices, Good Manufacturing Practices, Good Hygiene Practices, and supporting programs such as Standard Operating Procedure and training programs and also Hazard Analysis and Critical Control Points system.

Good Agricultural Practices (GAP) Include practices improving conventional production and produce handling methods - starting from the selection of the soil to be cultivated - and activities related to production and handling of produce in the field, always stressing SAFETY.

Good Manufacturing Practices (GMP) Include practices preventing and controlling post-harvest hazards affecting produce safety and having minimum effect on workers and the environment from the chain standpoint, hazard prevention and control in stages previous to production and harvest of produce using GAP are essential to assure success of implementing Good Manufacturing Practices programs. The objective is to ensure that safe raw materials go into the packaging plants with assured safety resulting from using Best Practices in post-harvest handling.

Good Hygienic Practices (GHP) Include all those measures and conditions required to prevent and control produce contamination hazards, mainly biological. In practical terms, the implementation of GAP and GMP (at primary and post-harvest stages) already includes all recommendations regarding hygiene practices to produce and handle safe products.

Standard operating procedures (SOPs): A written, detailed and accessible description for use by personnel explains how each operation is performed, including cleaning and maintenance procedures.

Pests' control: Pests are a serious threat affecting safety and life of foods and result in quality losses and increasing chances of food-borne diseases. Programs precluding access, infestation and monitoring for their appearance and eradication are necessary preventive measures.

Waste handling or management: Appropriate measures should be taken to remove and store waste and trash produced; these should be absent from areas where fruits and vegetables are handled and stored or from working zones and outlying areas.

Monitoring: Procedures checking the efficiency of the maintenance sanitizing systems should be applied and sampling of outlying areas; areas in contact with produce should be implemented and examined regularly to reflect possible changing conditions.

Recall procedures: Efficient procedures should be used, allowing for the complete and fast recall from the market of fruits and vegetables showing safety hazards. Until a decision is taken, recalled products should be kept under surveillance to be destroyed, not used for human consumption or declared safe.

Traceability is the capacity to identify a product origin: where it was produced, inputs received, tracking post-harvest handling, and through appropriate records, following it along the supply chain.

Personnel hygiene: Personnel may become a safety risk for fresh fruits and vegetables if they have inadequate personal cleanliness, if they suffer from or carry diseases or have an inadequate personal behavior. Strategies to improve personal cleanliness (protective clothing, hand washing) and practices promoting adequate behavior at work forbidding eating, smoking or spitting should also be adopted to safeguard safety.

Hazards Analysis and Critical Control Points System (HACCP) : It is a control and systematic recording methodology, that performs a detailed analysis of the whole production system to identify physical, chemical and biological hazards and those points where control measures should be applied to minimize or reduce risks to acceptable levels.

Food Safety and HACCP

ASI Food Safety Consultants

Introduction

It is essential that all possible measures be taken to store and distribute food and other products safely. Complying with basic Good Manufacturing Practices (GMP) is not sufficient, as food can still become contaminated and consumers can fall ill and sometimes die. Even now, thousands of people die each year from eating food that was contaminated during preparation or storage.

One must be proactive rather than reactive. It is necessary to follow the principles of HACCP (Hazard Analysis Critical Control Points) and ensure that food does not endanger human health. In order to achieve a hazard-free product, it is necessary to have in place a HACCP program that prevents, eliminates, or controls hazards. As these hazards can be physical, chemical, or microbiological in nature, the operation of a distribution center has to consider all three categories. All of these hazards can be prevented, eliminated, or controlled by having food safety programs in place and by educating employees to recognize hazards.

Physical hazards can get into exposed product through poor storage practices. In areas where product is exposed—repack and salvage areas and produce storage areas—it is essential to prevent items dropping into the product. In areas where the product is not exposed, it is essential to keep the product covered properly.

Chemical hazards can result from commingling, improper pesticide use, improper use or storage of cleaning chemicals, etc. Employees need training in how to prevent chemical contamination of the food products.

Microbiological hazards can already be in the food at low levels, and not storing the food at the correct temperatures can cause pathogens to grow to dangerous levels. It is important to keep potentially hazardous foods cold unless they are stored in hermetically sealed containers such as cans. Microbiological hazards can also get into ready-to-eat foods through improper storage practices that result in cross-contamination from a raw food to a ready-to-eat food. If food is exposed, poor employee health can lead to contamination if the employee has a communicable disease (e.g., *Salmonella typhus*, *Shigella*, Hepatitis A, etc.).

Operating a food distribution center using HACCP principles requires you to be trained in HACCP and to have HACCP programs in place. These programs should be monitored regularly and their effectiveness verified by an outside group (corporate quality assurance, consultant, etc.). ASI Food Safety Consultants can help you be prepared for the twenty-first century by educating your employees and helping you put HACCP programs in place.

The benefits of operating a food-safe warehouse are:

- Safe and wholesome food.
- No people sick or dead.
- No food discarded.
- No potential law suits.

- Competitive advantages.

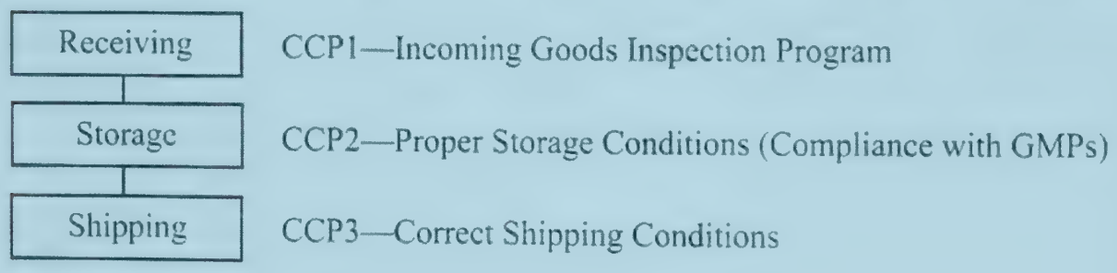
A HACCP program is essential for the safe storage and handling of potentially hazardous foods such as meat, poultry, eggs, dairy products, fish, shellfish, etc. These foods are, by their nature, capable of supporting the growth of harmful and toxicogenic bacteria. If not handled properly, they can be the cause of major foodborne illness outbreaks resulting in serious illness and/or death. It is essential that these products be handled correctly during distribution and storage.

Raw and ready-to-eat products need to be kept separated from each other so that raw food or raw food juices do not contaminate ready-to-eat foods. Most raw foods, especially meat, poultry, seafood, fish, etc., contain harmful bacteria (pathogens) that are killed by proper cooking. However, if these bacteria are allowed to come into contact with ready-to-eat foods that are not going to be heated, they can and will lead to foodborne illness outbreaks.

The development of a HACCP program for food distributors is necessary:

- To prevent cross-contamination from a raw food to another food (raw or ready-to-eat) which is not going to be heated.
- To avoid temperature abuse that would allow harmful bacteria to grow to levels at which cooking would not kill all the bacteria or remove the toxins (poisons) formed.
- To avoid other contaminants of a physical or chemical nature.

Contamination of a raw potentially hazardous food with blood or juices from another potentially hazardous food (e.g., beef contaminated with drippings from pork) can result in a foodborne illness. This is because the temperature to which beef is cooked is less than that to which pork is cooked, hence failing to kill any *Trichinella spiralis* that may have dripped onto the beef



from the pork.

The flow of product through most distribution centers will be as follows:

Critical Control Point: Incoming Goods Inspection Program

Every facility should have a formalized, written incoming goods inspection program. This program should be designed to be preventive, participative, and practical. It should prevent the facility from receiving adulterated product by involving the employees in practical inspection techniques. Without an effective program, a facility is inviting problems in. Once the problems are inside, they are difficult to remove, and any publicity can be disastrous.

This section is intended to help set up an effective incoming goods inspection program, which will prevent rodents, insects, and contaminated goods from entering your facility. The program begins with the arrival of the trailer and ends with the goods being accepted and placed in the

facility's storage areas.

Examine every trailer for the presence and integrity of a seal. Then examine the inside of the trailer for cleanliness, odor, physical appearance, temperature, and the mixture of products.

- **Seal**—Do not receive if the seal is broken. Many manufacturers seal their trailers after loading to ensure that you receive their products in the finest condition with no tampering or pilferage.

- **Cleanliness**—The transportation of food products needs to be done in trailers that are clean and free of general debris and garbage. If the trailers are not kept clean, they become breeding grounds for pathogens (foodborne illness-causing bacteria), molds, rodents, and insects. Reject all trailers that show signs of spillage, old product, rodents, or insects. These problems do not limit themselves to the trailers, but will result in contaminated food products and possibly food poisoning.

- **Odor**—A trailer may look clean, but if it has an odor, which could be chemical, pesticidal, moldy, sour, etc., this odor is indicative of an insanitary trailer. The odor could have permeated soft-pack food products and contaminated the product. Reject the trailer so as to not take a chance.

- **Physical appearance**—If the trailer has holes in it to the outside, then the product has been exposed to road dirt and weather. Reject the trailer, as the product may be contaminated. If the holes are in the inner walls only, check for signs of rodents or insects; if clean, accept.

- **Presence of rodents or insects**—If any evidence is found of rodents or insects in the trailer or on pallets, reject the entire trailer of product.

- **Temperature**—It is essential to keep frozen product frozen (i.e., below 0°F or -18°C) and refrigerated foods cold (below 41°F or 5°C). Check the temperature of the trailer to ensure that the refrigeration unit is working properly and keeping the food cold. Reject the trailer if it is not cold when carrying frozen or refrigerated foods.

Truck drivers have been known to turn the reefer units off to save the cost of diesel fuel that runs the reefer. The temperature of the actual food must also be taken along with the temperature of the trailer itself. If you are not sure that the food has been kept cold at all times during transportation, you may want to have suppliers of certain high volume critical food items place a temperature recording device on the trailer. This can be nestled among the products without the driver knowing and it will record all temperatures of the trailer during transporting. Calibrate the dial thermometer first. Put it in a glass of melting ice for five minutes and it should show 32°F (0°C).

When receiving frozen or chilled merchandise, insert the thermometer into the master case and try to touch the package with the metal end of the thermometer for a few minutes.

Guidelines for Food Trailers

- **Clean**—Trailers should be free of all trash and old food residues.

- **Good condition**—They should be free of holes in the outer body that would allow road dirt and weather in.

- **No interior holes**—If lined, there should be no holes between the liner and the truck wall

that could harbor insects and rodents.

- **Used for food only**—Do not use the same food trailer to haul garbage, toxic chemicals, tires, pesticides, and/or other highly aromatic items with food product.
- **Odor free**—Must be odor-free at all times.
- **Rodent/insect free**—The trailer should be free of birds, rodents, insects, flies, etc., and all their excrement and urine.
- **Washed regularly**—The inside and outside should be washed to remove general dirt and bacteria.
- **No splintering wood**—There should be none on doors, walls, or ceilings that could adulterate the food.
- **Refrigerated trailers**—These units must be capable of holding food below 41°F (5°C) and condensate from coils must not drip onto food.
- **Freezer trailers**—Units must be capable of holding food below 0°F (-18°C). Mixture of contents—The shipment of food products needs to follow the same guidelines as the storage of food product. Products should be transported under conditions that will not result in cross-contamination. Examine the trailer for any pesticides or other toxic chemicals that could contaminate the product. Look for cleaning chemicals or household products that could spill onto the product or contaminate food through strong odor. Look for storage of raw products (beef, pork, fish, shell eggs, etc.) over cooked or ready-to-eat products. This could lead to foodborne illness outbreak. Look for any non-food products (tires, batteries, etc.) that could leak or generate an odor that would contaminate the food product. If any conditions exist that may have resulted in an adulterated product, then reject the trailer.

Product Inspection

It is necessary to examine the product in the trailers to look for package integrity, temperature, product label, age of product, approved product, evidence of rodents, insects, etc. It is not possible to examine every bag or box of product or to examine every pallet of product. The facility has to develop a program of inspection frequency and depth that is based on:

- The nature of the product and its possibility of causing a foodborne illness, or its probability of bringing insects or rodents into the facility.
- The number of shipments received from the supplier.
- The supplier's track record of providing top quality products.

The product in every trailer needs to be examined, at least visually, by the unloader. For product that is most susceptible to rodent or insect infestation, three pallets of products—one taken from the rear, one from the middle, and one from the front of the trailer—should be examined thoroughly. This should be done using a bright flashlight and, if rodent contamination is suspected, a black light. Repalletizing of the products may be necessary to do a thorough inspection.

Particular attention should be paid to soft-pack food items such as beans, rice, flour, grits, cake mixes, and doughnut mixes. During hot, humid weather in the summer months, stored product insects may develop from within these commodities and emerge through the bag in the larval

stage. When this occurs, the receiving inspector, again using a strong flashlight, will see small holes in the bags about as big as the tip of a ball point pen. Do not receive bags or pallets of product if insect emergence holes are noted in the bags. These holes are a good indication of insect infestation. It is recommended that if one pallet is infested within the trailer, the entire load should be rejected.

The same would hold true for pest evidence. If rodent pellets or bird droppings are noted on one pallet of product, the entire load should be rejected. Other items that need to be closely examined with the strong flashlight include charcoal and any paper products where rodents could nest. Cases of canned product can be infested with cockroaches as they only need the glue on the case as their food source.

Cases and bags of products should be examined for the following:

- **Package integrity**—Damaged packages indicate possible rodent entry, insect activity, or tampering. Any of these could result in contaminated product. Reject the product. Swollen cans could be an indication of botulism. Reject the product. Dented cans could contain contaminated product. Reject the product.

- **Temperature**—Frozen products need to be 0°F (-18°C) or below; reject if 15°F (-9.4°C) or above. Use a metal thermometer and insert it between the packages of product. Refrigerated products need to be kept below 41°F (5°C). Place the thermometer between the packages and reject if over 50°F (10°C). Note on potentially hazardous foods: Harmful bacteria grow in food when temperatures are allowed to rise above 41°F (5°C). It is essential when receiving refrigerated food that the receiver check temperatures of the product at random and keep records. If the food is refrigerated, ideally it should be below 41°F (5°C), and so should the trailer. Therefore, food above 50°F (10°C) would be unacceptable. Record on Potentially Hazardous Foods Receiving Log and keep on file. If the food is frozen, it should be below 0°F (-18°C) and show no signs of thawing and refreezing. If it is over 15°F (-9.4°C) or showing signs of thawing and refreezing, the product should be rejected. Report on the Potentially Hazardous Foods Receiving Log.

- **Product label**—All cases, pails, etc., of product need to be legally labeled as to contents. Reject all product that is not labeled.

- **Age of product**—All products have shelf lives that indicate by when a product has to be consumed. For dairy products, this is only a few weeks. Examine incoming goods for the amount of shelf life left for the product and reject the product if the remaining shelf life is zero or so short that your facility has insufficient time to receive product, store it, and use it or reship it before its shelf life is zero. It is recommended that soft-pack food items not be received if over 3 months old.

- **Approved product**—Examine the product to ensure it is an approved product and that it meets your specifications. This may entail merely a physical examination of the product label and the package size, but could also include chemical or microbiological analysis at a laboratory. Reject any product that is not approved or does not meet your specifications.

- **Evidence of rodents or insects**—If there is any evidence of rodents or insects in or on the product or package, then the entire trailer of product should be rejected. If live or dead insects, rodent pellets, or any other pest evidence is collected, it is recommended that these

findings be placed in a small vial with at least a 50% concentration of alcohol. This will keep the specimens intact and fresh in case the supplier wants them for any reason. Be sure to collect plenty of samples if a load is going to be rejected because of pest evidence. An advised method for picking up live or dead insects or insect fragments is to use a small model paint brush to keep the item intact, as opposed to squeezing it with finders or tweezers.

Incoming Goods Inspection Log

Trailer	Yes	No
Seal number		
Dirty		
Noticeable odor		
Poor physical		
Insect/rodent/bird evidence		
Not cold (if applicable)		
Mixture of product could lead to cross contamination		
If any "Yes," then reject the trailer.		

Product	Yes	No
Packaging damaged		
Frozen product over 15°F (-9.4°C)		
Refrigerated product over 41°F (5°C)		
Not labeled		
Remaining shelf life too short		
Not approved		
If any "Yes," then reject product and state what product and why.		
Insect/rodent/bird evidence		
If "Yes," reject entire trailer.		

An example of an incoming goods inspection check-off list is included. It is recommended that you use this list.

Additional Notes on Incoming Goods Inspection

The person responsible for accepting or rejecting a shipment should have full responsibility and authority to do so. He/she should not have to run to a supervisor's office for permission, but should be able to make the decision right on the receiving dock. The president or division president should back up this person's decision.

It is also advised to remove, if practical, all shrink wrap at the receiving dock, especially from around soft-pack food items, so that the products are more easily accessible to the self-inspection program being done in the facility. Removal of shrink wrap will also keep the product at a lower temperature, so that insects will not develop as rapidly within the product. Leaving the shrink wrap on sometimes allows it to work as an incubator for insect develop-

ment stages.

Besides an in-house self-inspection program, the incoming goods inspection program is probably the second most important. Throughout the years, it has been ascertained that 75% of the pest problems that develop within a facility have been brought in from a shipment by truck or boxcar.

A pyrethrin aerosol bomb can also be a useful tool during the receiving process. A pyrethrin aerosol will disturb cockroaches and even stored product pests. Pyrethrin aerosol can be sprayed around and in holes of the pallet itself to see if any insects exist in those areas. The mist will then infiltrate back up through the stack and upset any insects that may be within the pallet stack so that they will be more visible. For receipt, in railcars or common carriers, of bulk ingredients such as rice, flour, barley, etc., pheromone lures can be used. These lures can be placed inside the bulk ingredients from the top of the railcar or truck and allowed to remain in that position for approximately 45 minutes to see if they attract any adult insects that may be in the product. If your facility can get the supplier to agree to place pheromone traps or lures for stored product pests in strategic locations throughout the shipment, it is an excellent tool for ascertaining if the shipment is infested. In many instances getting suppliers to agree to this requires some tough negotiations.

If these guidelines are followed regularly and a track record is established with the supplier of what the facility will reject, then problems will likely not be brought into the facility. A good incoming goods inspection program is preventive, participative by the employees, and practical. You cannot look at everything, but you cannot afford to look at nothing.

Critical Control Point: Proper Storage Practices

One of the major causes of food, food packaging, and food supplies becoming contaminated is cross-contamination from one food to another or contamination by a non-food product. It is essential therefore, when storing foods, food packaging, and supplies that there be a plan that keeps the foods away from materials that may contaminate them and avoids commingling.

Obviously, if the food is in a bag or a soft pack or exposed as produce is, it is more vulnerable to contamination than if it is in a can, pail, or glass container. These rigid containers, however, may also be a problem, as a contaminant on the outside of a container can find its way inside when the container is opened or, in the case of a beverage can, the consumer drinks from the container. The rigid-type package certainly protects the product from splash or absorption of odors; but, unless the user washes the outside of the container prior to opening, the contaminant could get inside upon opening.

Dry Storage

Store all items off the floor and always store household products one aisle away from food products. (This includes back-to-back storage). A separate warehouse or a walled-off room for non-food products is even better.

Products to keep away from food, food supplies, and food packaging include, but are not limited to, the following:

- Bleaches

- Laundry detergents and fabric softeners
- Floor cleaners, floor waxes, floor strippers
- Air fresheners
- Drain cleaners
- Shampoos, hair conditioners
- Perfumes and cosmetics
- Dish detergents
- Toilet bowl cleaners
- Hand soaps

In addition, other products that could either spill onto a product or contaminate it with an odor need to be kept away from food products. For example:

- Personal care products
- Charcoal, lighter fluid
- Pesticides
- Forklift batteries, tires
- Hand lotions
- Non-prescription medications
- Paint removers
- Nail polish removers
- Warehouse cleaners
- Motor oils, windshield washer fluids, automotive products

Products that are returned from customers or that are damaged need to be segregated from regular products so that they do not contaminate the regular products. These returned or damaged products also need to be stored until reworked so that they do not contaminate each other. A reclaim or salvage room or warehouse is greatly preferred over using an area in an existing warehouse.

Aisles and Spaces

The provision of non-traffic aisles between rows of palletized goods and especially at floor-wall junctions is a necessity in establishing and maintaining good warehouse sanitation. The Good Manufacturing Practices (GMPs) of the US Food and Drug Administration state in Section 110.20(b) (1) Plants and Grounds: "Provide sufficient space for such placement of equipment and storage of materials as is necessary for the maintenance of sanitary operations and the production of safe food." This sentence is typical of the "performance standard" style of many federal regulations. That is, it does not state that an 18-in (45-cm) or larger setback space is required. And it does not state that any white floor stripes must be painted. It throws the responsibility for meeting the "non-contamination" requirement directly in any warehouseman's or food firm's lap, and this section will discuss the aisles and spaces issue and recommend for their establishment and use.

Perimeter access space is a general phrase describing space between storage and walls. Purposes are:

- To prevent contact of ingredients or finished products with rough surfaces and/or dirty walls.
- To provide a space for inspection for ruptured and/or spilling containers and for taping of tears.
- To provide access for pest control services including inspection and "crack and crevice" control applications. Rodent control devices such as automatic mouse traps (Ketch-Alls, Tin Cats, snap traps, and glue boards) can only be installed and used effectively by provid-

ing perimeter access spaces.

The actual width of spaces should be 18-24 in (45-60 cm), and should be provided at all walls even when equipment or non-food goods are stored in certain areas of the food warehouse. The actual distance of space is not the important thing, as long as it is sufficient to permit a normal-sized person to work in it. Remember to provide a passage space out from any vertical posts or other such attachments to any wall.

Perimeter access spaces should be maintained within cooler and freezer rooms as well as larger warehouses to ensure good air circulation and to avoid product damage. Frozen foods crammed against freezer walls encourage ice deposits on walls.

- **Floor striping**—White stripes at floor-wall junctions (or even 4-6 in [10-15 cm] up the walls) not only reflect a positive sanitary appearance but also make inspection much easier. These are highly recommended, but are not required by the GMPs.

- **Bump guards**—To positively ensure that pallets are not set down too close to walls, various types of barriers are sometimes used. Without doubt, the stronger they are, the better—they should be overbuilt or over engineered to be effective. Lengths of right angle iron anchored to the concrete floor or virtually any guards constructed partially or completely of wood are usually bent, torn loose, or splintering. Despite the greater expense, lengths of cement-filled piping are most effective. Stepped or built-in concrete curbs 18 in (45 cm) wide or more appear satisfactory, but sanitation problems still occur where pallets actually abut against the rise of these curbs. Accumulations of crushed spillage, dirt, and pest harborages all remain in inaccessible right-angle contacts when using such curbs. Built-in curbs, therefore, are not recommended at time of construction of a new warehouse.

- **Accessory aisles**—Palletized storage should not be stacked in solid blocks. Leave an 18-in (45-cm) minimum personnel aisle extending at right angles to walls between every 2-3 rows of pallets. This is necessary even if products are nonfood (such as empty cans or bottles, other packaging supplies, or extra pallet boards). Floor stripes painted to designate these aisles are a big help in storage orientation and add to sanitary appearance.

- **Shelf rack perimeters**—Some warehouses are constructed with dimensions that prevent provision of 18-in (45-cm) perimeter access spaces. Here, great care must be taken not to set shelf/rack storage in so far that it contacts walls. At floor level, an absolute minimum 6-in (15-cm) floor-wall junction should be maintained between pallets and the wall base. Snap traps and glue boards can usually be used in these narrow spaces, but placement and servicing demand careful use of a rodent control unit plot map by the pest control operator.

- **Pest problems**—Aside from the obvious need to avoid dirtying or rupturing food ingredient or product packages or containers by contacting walls, blocked or non-existent perimeter access spaces can be a primary harborage for pests in a warehouse or distribution center. As mice and rats have poor eyesight and they use their vibrissae, or whiskers, in contact with a wall to orient themselves, they prefer to run alongside walls. Pallets crammed against walls provide an excellent harborage for rodent pests. Floor-wall junctions, especially in precast building construction, may have unsealed expansion joints or cracks. These can harbor insects and, in many areas, can allow subterranean termites from beneath the floor slab to actually build their shelter tubes up interior wall surfaces. Termites will also tube up from unsealed floor expansion joints and attach to pallet boards or befoul cartons or containers. Many other, more common crawling insect pests will harbor (or actually breed if old

spillage is present) in blocking spaces. These may be ants, cockroaches, earwigs, ground beetles, fruit flies, flour beetles, saw-toothed grain beetles, sow bugs, pill bugs, or others.

Provision of both within-storage aisles and good, complete, perimeter access spaces is a key basic principle in establishing and maintaining a sanitary warehouse operation.

Storage of Potentially Hazardous Foods

When storing food products, we must always be aware of the possibility of the product becoming contaminated. This can be from insect or rodent infestation, contamination by foreign substances (glass, cleaning chemicals, etc.), or by cross-contamination with microorganisms. This section deals with how to prevent food products from becoming contaminated.

Contamination is defined as "the unintended presence of harmful substances or microorganisms in food." Contamination with microorganisms is commonly referred to as cross-contamination, which will be discussed later. One of the leading causes of contamination is placing product or cases of product directly on the floor in a storeroom, cooler, or freezer. Here the product is subjected to floor dirt from sweeping, mopping, or direct contact with the floor. If the product itself does not become contaminated, the bottom of the case does, and this will inevitably be placed on a work surface which it will then contaminate, thus leading to contamination of the next food product placed on the surface. Therefore, food should always be stored 6 in (15 cm) off the floor or on easily movable pallets or slip sheets so the floor can be cleaned without contaminating the product. Likewise, product should be stored 18 in (45 cm) from the wall where possible. This allows for keeping the walls clean, enacting an effective rodent control program, and maintaining adequate circulation in coolers and freezers. Where an 18-in (45-cm) aisle is not possible, at least make sure that the product is not touching the wall.

One must be constantly on the lookout for areas that can lead to contamination, and in so doing eliminate the possibility of contamination before it happens. Many foreign substances cause contamination of food product during storage. Some examples are glass from broken, unprotected lights; peeling paint from walls or ceilings; rust from ceilings, walls, or shelving; grease or oil from conveyors or electrical motors; and dirt from air vents or ductwork. Contamination can come from water that condenses on the cooling coils in refrigerated rooms or freezers. This water is non-potable (not drinkable) and can lead to contamination if allowed to drip onto cases of product. The US Food and Drug Administration considers any product or cases of product that have been covered with condensate water or ice (in the case of a freezer) to have been held under unsanitary conditions. This entire product needs to be inspected immediately for contamination. If the product has not been in contact with condensate, it should be repacked in a clean box and returned to the freezer or cooler. Clean up the condensate, repair the condensate drain, and do not store any product below the defective unit until the problem has been corrected.

Commingling, or the storage of food product, especially soft-pack product, with non-food product like cleaners, pesticides, heating fuel, etc. can and will lead to contamination. Non-food product is often toxic (poisonous) or highly perfumed or both. By storing it near food products, the risk of contamination is high, and there is a real possibility of somebody becoming sick. Wherever possible, cleaning chemicals, heating fuels, household products, etc. need to be stored in separate areas from food. In a warehouse, they should be stored in separate aisles, but where this is not possible hazardous product should always be stored on the lower racks, so that it cannot leak or spill onto food. Pesticides are required to be stored in a separate room or cabinet, preferably locked.

Cross-contamination is the transfer of harmful microorganisms from one food to another by means of a non-food surface (utensils, equipment, human hands) or directly from one food to another. The most common means of cross-contamination in food storage is directly from one food to another. For example, shell eggs have been shown to be a leading source of *Salmonella*, so these need to be stored on a lower shelf and not over any product other than eggs. Then, if an egg gets broken and drips down, it does so either onto other shell eggs or onto the floor and not onto another food product which may be ready-to-eat, such as lettuce or cooked ham.

Raw meat and poultry contain in their blood and juices many harmful microorganisms which are killed during the cooking process. However, if in storage these juices are allowed to drip onto cooked product, the cooked product will become contaminated. As this cooked product is not likely to be reheated or cooked again, the microorganisms could cause people to become sick. Therefore, never store raw product over ready-to-eat product; always store cooked product over raw.

Microorganisms that are associated with different meat, poultry, and fish products are killed by heating to different temperatures. It is thus important that meat products (veal, beef, lamb, etc.) not become contaminated with juices or blood from poultry products (chicken, turkey, etc.) or with juices from fish (salmon, snapper, etc.) or vice versa. Therefore, always store beef over beef, poultry over poultry, and fish over fish, or store these products on the bottom shelf over nothing. This will avoid cross-contamination from one product to another. Reduced oxygen packages are susceptible to tears or punctures that let juices leak out, so these packages need to be treated with the same care. The storage temperatures for these products should be 41°F (5°C) or below.

In order to prevent growth of harmful bacteria in potentially hazardous foods, it is necessary to keep the foods below 41°F (5°C) or, if frozen, at 0°F (-18°C) or below. Therefore, monitor and record daily temperatures of all coolers and freezers using a temperature recording chart, a computerized system, or a daily log such as the one below.

If the temperature of the cooler or freezer is too warm, take the temperatures of several food items to ascertain if this is a serious problem or a temporary condition. If frozen food has thawed and its temperature is not above 41°F (5°C), move it to a cooler and ship it soon. Do not refreeze. If it is a refrigerated and potentially hazardous food and the temperature has risen above 50°F (10°C), it should be discarded.

When coolers are over 41°F (5°C) and freezers are over 0°F (-18°C) a corrective action needs to be taken to correct the situation. This should be noted on the temperature recording chart, in the computer, or on the daily temperature log.

Storage of Frozen Foods

The purpose of freezing food is generally to extend its shelf life. (The exceptions are foods which are frozen by their nature, such as ice cream other novelty items.) The storage of foods at 0°F (-18°C) or lower stops the growth of harmful bacteria (pathogens) but does not kill all of them. *Salmonella* has been isolated in whole egg products and meat after several years in frozen storage. Spores of *Clostridium perfringens* and *Clostridium botulinum* have considerable resistance to alternate freezing and thawing at a temperature as low as -58°F (-50°C). Staphylococcal toxin can withstand 0°F (-18°C) for several months. Trichinella spiralis, the parasite found in pork and wild game, however, is killed after 30 days at 0°F (-18°C).

The mechanism which prevents bacterial growth is the reduction of water activity in the food to below 0.85 by freezing the water in the food. This makes the water unavailable to bacteria for use in its growth. Freezing also reduces deterioration due to oxidation or enzymes. However, freezing never improves the quality of a food; it only maintains the status quo for longer periods of time than does refrigeration.

It is important to freeze foods as rapidly as possible to retard bacterial growth and to prevent large ice crystal formation and the subsequent possibility of cell structure rupturing. Specialized equipment is required to freeze foods rapidly. It cannot be accomplished in commercial freezers, which are designed only to hold already frozen foods and should never be used to freeze foods. In commercial freezers it will take much too long to freeze the center of the product. The resulting loss of quality due to slow freezing may be equivalent to the loss of several months of storage at 0°F (-18°C). Storage of foods in freezers increases the chances of contamination unless the food is properly handled. The longer food is kept, the greater the risk of contamination. It is essential that foods, even those in a freezer, be handled following good basic rules.

- **Receiving frozen product**—All frozen product should be received at 0°F (-18°C) or below. Never accept product that is above 10°F (-12.2°C) or shows signs of having been thawed and refrozen. Product that has torn, ripped, or punctured packaging should be rejected.

- **Product dating**—Prior to being placed in a freezer, all product should be dated the day of receipt. This helps to ensure that the product is rotated using the first-in, first-out (FIFO) procedure, in which the oldest product is used first, thus limiting the storage time of product. Product stored in a freezer keeps longer than that stored in a refrigerator, but the food should not be kept frozen indefinitely.

- **Length of storage**—Although frozen food that has been properly covered or wrapped can be stored a long time, it is not a good practice. All product should be rotated every three months and should not be kept longer than six months. Exceptions to this guideline should be kept to a minimum and limited to food items that are not potentially hazardous. (Potentially hazardous foods are those that under the right conditions will support the rapid growth of pathogens. Examples of these foods are: milk and milk products, eggs and egg products, all meat, poultry, fish, edible crustacea and shellfish, tofu, boiled and baked potatoes, and cooked rice.)

- **Product protection**—All food items should be kept covered at all times to prevent freezer burn (dehydration due to moisture loss) and contamination from airborne dirt and microorganisms. Any package that is opened or torn must be immediately sealed or repackaged. This helps to prevent contamination of product.

- **Storage conditions**—Product should be stored at all times to protect it from contamination and to allow adequate air circulation to be maintained to keep it frozen. All product should be a minimum of 6 in (15 cm) off the floor, 3 in (8 cm) from the walls, and 12 in (30 cm) from the ceiling. (Note: If your freezer has sprinklers, product must be 18 in (45 cm) from the sprinkler heads.) Product should be stored on slatted shelves or pallets to allow for air movement between product cases. If the product is on slip sheets, the lowest product should be on a pallet off the floor. Never store product directly in front of cooling fans because this will affect the air circulation flow. As temperatures in freezers generally vary (it is warmest farthest from the fans and closest to the door, especially in larger freezers), it is a good practice to store potentially hazardous foods in the coldest part of the freezer.

Daily Temperature Log for Coolers and Freezers

Month _____ Equipment _____

Day	Time	Temperature	
		External Guage	Internal Guage
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

Day	Time	Temperature	
		External Guage	Internal Guage
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			

Next to temperatures of coolers over 45°F (7.2°C) and freezers over 0°F (-18°C), note the corrective action taken.

- **Defrost cycle**—To maximize the efficiency of air cooling systems. it is necessary to periodically defrost the cooling coils. To minimize temperature rise in the freezer, this should be done at those times of the day when the activity in the freezer is at its lowest. The condensate from the coils needs to be caught in a drip pan and conveyed to a drain outside the freezer. This condensate of dirty (non-potable) water should never be allowed to drip onto product or cases of product. This would constitute storing product under conditions which may allow it to become contaminated. Any product or cases of product that have become contaminated in this way need to be disposed of immediately. Do not store any product under this condensate until the drip has been eliminated or is conveyed away from the product.

- **Snow problems**—In areas where humidity outside the freezer is high, a problem with snow can occur. This is the formation of ice crystals on the ceiling and metal shelving frames in freezers due to warm, humid air entering the freezer and being rapidly cooled down. This problem generally occurs near the entrance door to the freezer, but it can occur where seams have been improperly installed or freezers have been poorly maintained, due to warm air being pulled through these loose or inadequately caulked seams. The snow

either melts during a defrost cycle and drips onto the product or falls down onto the product and gives the effect of snow covering the product. Because this snow (or the water that forms from it) is unclean, storing product under these conditions may result in contamination. Any product that has been contaminated by snow should be disposed of immediately. (Note: Placing a sheet of plastic over the cases of product to protect them from snow or water drippage is adequate protection.) If the problem of snow is caused by a loose seam, tighten the panels and/or recaulk. If the problem is at the door, try an air curtain at the door (blowing away from the freezer) or a plastic curtain at the door or, if the freezer is large enough, install a vestibule and use heaters.

- **Thawed product**—If the product in a freezer thaws due to a malfunction in the machinery, the temperature of the product will have risen. As long as the product temperature has not exceeded 41°F (5°C), the product may still be used; however, it should be removed into refrigerated storage and used as soon as possible, never refrozen.

- **Thermometer**—All freezers should be equipped with an accurate and readily visible thermometer. The probe of the thermometer should be positioned so that it is measuring the temperature of the warmest spot in the freezer. (Note: The warmest spot in the freezer is generally found near the door or the point farthest from the cooling coils.) The thermometer needs to be accurate to within ± 3°F (± 1.7°C) and calibrated on a frequent basis.

- **Cleaning**—The freezer needs to be on a regularly scheduled, weekly cleaning program which should include floors, walls, shelves, cooling coils, fans, condensate pan, and drain line. This should involve a general cleaner designed for use in freezers followed by a quat-type sanitizer. The sanitizer should be flushed through the condensate line to destroy any environmental microorganisms, especially *Listeria*.

Vapors That Can Contaminate Packaged Food

Food stored in a warehouse (cooler, freezer, and dry) can be contaminated by certain chemicals, either from liquid dripping onto the container and seeping through into the food product or from the vapors of a solvent material used nearby permeating through the outside container and contaminating the food. This can occur even if the food is packaged in master cardboard containers, polyethylene plastic, or sealed in a reduced oxygen package. Every odor that occurs in a warehouse situation should be investigated, including those coming from any food production areas.

One of the first steps to investigate an odor is to see if there has been any prior history in the facility with that particular odor. An example would be if painters are painting in a certain area of the facility. Has that paint ever contaminated food product before? The same would hold true for cleaners, pesticides, highly fragrant household products, sanitizers, insecticides, propane-powered forklifts, or any other odors or fumes that may occur in the facility.

If outside contractual work is going to be performed in or around the facility, it is important to ask questions about the chemicals that will be used. Will the chemicals being used violate packaged food product? Ask the supplier or user of the material whether they know if it will or could contaminate your food product. Ask the supplier whether the material is either USDA-authorized or FDA-approved. Is there any food additive tolerance, food clearance, or defect action level? Try to get these in writing.

Liquid materials have violated food products stored in a warehouse in the past. Be on the look-

out for any materials containing aliphatic and aromatic petroleum solvents. Their vapors have been known to permeate through polyurethane plastic and master cardboard cases and contaminate food products. Be particularly suspicious of concrete curing compounds, floor sealing compounds, and caulking compounds.

It is imperative to have sample labels and Material Safety Data Sheets for any materials used in or around your facility. Ask the supplier or user about the history of their materials. If certain construction materials are going to be used around food product, make sure that the facility is properly ventilated so that the material vapors can escape. Some material vapors have also penetrated Styrofoam and have contaminated food already packaged for shipment yards away.

It is your responsibility to make sure that the user of the materials follows the label directions explicitly regarding preparation, coverage, methods, application rates, medical attention for possible overexposure, recommended safety equipment, and disposal of empty containers. Be sure that the outside contractor is legally responsible for the odor of the chemicals that they are using. In the US, the warehouse is ultimately responsible, even if an outside contractor causes adulteration or contamination.

If a strong odor does occur, especially if it makes the eyes water and the nose drain, it would be prudent to open some food containers to see if these vapors have penetrated into the food. Perform tests as necessary. If food is contaminated, segregate it immediately to be certain that it does not get shipped into the market. This pertains to soft-pack food items. Materials packaged in cans or bottles should be safe.

Pest Control Programs

This section reviews technologies aimed at suppression, prevention, exclusion, and control of rodent pest problems.

Formal Program

A formal, structured rodent control program must be established and maintained to do an effective job of guarding against the inadvertent introduction of rats or mice on incoming goods and controlling them if they do gain entry. Responsibility for the program should be assigned to a single individual—usually the sanitarian—who will administer this important part of the overall food safety program.

Any rodent control program should be written as standard operating procedures, should address the items discussed here, and should be distributed to all affected departments. Included in the program should be coordination of any maintenance activities regarding rodent exclusion; the procurement, use, and disposal of all rodent control tools or rodenticides; and the maintenance of a file of records, references, and so forth.

Incoming raw materials and ingredients should be inspected for rodents or damage, using flashlights and ultraviolet "black" lights. Pallet boards should be inspected for old excreta pellets, as should the well or chimney of palletized goods. Inspection tools, including standard and ultraviolet lights and rodent urine test kits, should be kept in good working condition and separate from any pesticide storage area.

Monitoring of storage practices is closely related to inspection. Perimeter setback spaces 18 in

(45 cm) wide should be provided and maintained at all interior floor-wall junctions. Ideally, this setback space on the floor should be painted using white enamel. Setback spaces must be kept free of litter and spillage. Palletized items most attractive to rodents (such as soft-bagged rice, flour, peanuts, or popcorn) should be shelf-racked off the floor.

Rodent evidence includes: excreta pellets, signs of feeding or gnawing (e.g., rounded holes in wooden walls), greasy rub or swing marks on overhead beams, suspect urine droplets fluorescing during black-lighting, or the sighting of live or dead rodents. To detect rodent tracks, lightly spread talc or other inert dust such as diatomaceous earth used in filtration equipment. Flour or powdered sugar should not be used for this.

It is useful to set up an employee sighting log, as this location information can help the pest control company and the warehouse sanitarian.

Understand that even a thorough job of physical rodent proofing will not guarantee a pest-free facility. Routine incoming goods inspections of all raw commodities or ingredients and packaging materials, along with other preventive rodent control tools—both inside and outside—are also essential. Food processing plants or warehouses must be constructed or modified to prevent entry of commensal rodent pest mice and Norway rats and roof rats.

Rats can live and nest in trash or in weedy areas outside an unguarded structure and enter to feed at night and exit near dawn. Mice will migrate from adjoining agricultural areas or other harborage into plants and remain there. This occurs most frequently, but is not restricted to, the fall months, when the temperature outside drops and rodents enter for warmth, shelter, and food.

The incisors, or upper teeth, of mice and rats curve inward. It is therefore difficult for them to gnaw into a flat, hard surface. Once a gnawing edge has been found, however, rodents can chew entry holes through wood, plastic, or even some aluminum or lead. Brick, concrete, or galvanized metal of heavy gauge should be used for rodent proofing or exclusion.

Other than the obvious holes in walls or cracks beneath door sills, rodents can also enter by burrowing under a building foundation (up to 4 ft [1.2 m] deep for Norway rats) or passing through unscreened ventilators on building roofs (roof rats). All openings greater than 0.5 in (13 mm) must be closed by impervious material to prevent access by rats. Holes greater than 0.25 in (6 mm) will permit mice entry. Any opening of sufficient size to permit passage of a pencil should be closed. Door sills must be tightly silled and desirably flashed with metal. Obviously, insect screened windows near the ground should be covered with 0.25-in (6-mm) mesh hardware cloth.

Poured concrete floors will usually deny access to burrowing rats, so long as the expansion joints at wall contacts are properly sealed. Where older, wooden-floored buildings need to be completely protected, a curtain wall of concrete can be poured extending 3 ft (91 cm) into the ground. A 4 in (8 cm) thick lip extending 1 in (2.5 cm) outward from the curtain wall base is desirable.

Any removable rat guards of sheet metal installed across the bases of freight door portal sides should extend at least 3 ft (91 cm) high and slope outward slightly. Floor drain gratings must remain in place and unbroken to exclude rat entry through drain lines.

Openings around virtually any piping extending through a building's walls should be completely sealed or flashed using concrete or sheet metal. Wads of steel wool or polymeric sealants

can be used temporarily to block mice, but these materials soon rust or age and crack and are not permanently effective. Galvanized metal guards may be fabricated around vertical pipes or anchored to walls. Circular ones can be fitted to loose cables, wires, hawsers, etc.

In regions where roof rats occur, all ivy should be removed from exterior walls, limbs of trees should be trimmed away from walls or roofs, and roof-to-wall eaves should be carefully inspected for possible access holes.

The following are specifications for recommended rodent proofing materials:

- **Concrete**—2 in (5 cm) thick or reinforced plates. Cement mortar: 3.75 in (9.5 cm) thick: 1:3 mixture.
- **Galvanized sheet metal**—6-gauge or heavier. Perforated grills: 14-gauge.
- **Brick**—3.75 in (9.5 cm); mortared joints.
- **Hardware cloth**—19-gauge (0.5-in or 1.3-cm mesh), galvanized or otherwise rustproof to exclude rats; 24-gauge (0.25-in or 6-mm mesh) to exclude mice and young rats.
- **Aluminum**—22-gauge for frames and flashings, 20-gauge for kick plates, and 18-gauge for guards.

There are few hard and fast rules governing rodent control technologies. All the following recommendations can be tailored to a particular need, and an effective program must have some built-in flexibility. Generally, it is better to have fewer tools that are regularly inspected and serviced than to have more tools that are not properly maintained. Traps are used primarily for mouse control, as rats are usually very trap-shy.

Multiple catch units (such as Ketch-Alls)

- Wind all units 7 full turns.
- Place them on either side of all ground-level doors and on either side of warehouse dock doors. (Mice can easily climb brick or concrete walls.)
- Set traps at 30-ft (9-m) intervals along inside of exterior walls.
- Stick service tags (for date and technician's initialing) on the underside of trap lids.
- Do not use automatic traps outdoors where rain and dust will render the mechanism useless.
- Number and designate all traps on a plot map.
- Service all traps every 4 days during summer and weekly during winter to avoid odors or flies breeding in carcasses.
- If a caught rodent is still alive, drop the trap into water to drown the rodent. Remove catches using gloves and/or long forceps, place in a polybag, and dispose in an exterior trash compactor or by burying.
- In coolers and freezers, Ketch-Alls should be placed on both sides of any doors that open to a warehouse area or a dock area. It has been observed that mice will live in coolers and freezers.

Snap traps

- Snap traps are best used for initial cleanout of mouse infestations.
- Place at various locations where rodent activity is noted—3-4 ft (91-122 cm) apart for mice.
- Use either baited or expanded trigger types.
- Recommended bait for mice includes:
- Small pieces of nutmeats.
- Pieces of soft, black (anise-flavored) gum drops.

- String, yarn, or plain cotton (all used for nest material).

Glue boards

- These, too, are used for cleanout of mice.
- They are best placed within bait stations or other shelters to protect them against dust.
- Inspect and service every 4 days, or more frequently, to avoid odors or flesh flies which originate in decomposing carcasses.
- Glue boards can and do accidentally trap insects and can therefore serve as a negative advertisement of stored-product pest insects to regulatory agency inspectors.

Baiting

- Baiting is primarily intended for rat control. Exposure should be restricted to nonfood areas. Do not use bait in raw ingredient or finished goods warehouses, to avoid the risk of spillage, tracking by forklift vehicles or employees' feet, and airborne dispersal of dust. In addition, bait can become insect infested.
- Various types of metal and high-impact plastic stations are commercially available.
- Use only the tamper-resistant type, and supply lids with plastic security seals or even small padlocks.
- Stick service tags on the undersides of all station lids.
- Various commercially available anti-coagulants or so-called "single-feeding" rodenticides are acceptable as bait. Use 2-4 ounces (57-113 g) of any type of bait in each station. Follow label directions. Wax or paraffin-based, weather-resistant bait blocks are generally preferred over cereal-based or pelletized formulations. Wax blocks are especially attractive to rats. They can also be hung from wires into hard-to-reach areas.
- Although liquid bait is particularly effective for rat control in hot, dry areas, extreme caution must be used to prevent spillage from the standard dispenser stations. Liquid bait should only be used for cleanout of actual rat activity and not as a preventive program.
- Bait station spacing recommendations:
  - At 50-ft (15-m) intervals along inner sides of property perimeter fence lines.
  - At 40-ft (12-m) intervals along exterior bases of plant or building walls.
- Stations should be numbered and locations listed on the rodent control plot map.
- All bait, with the exception of bait blocks stamped into active rat burrows, should be contained within tamperproof bait stations and preferably fastened inside. Stations should be anchored using spikes or long nails or they should be tied to fences to avoid overturning. Tying is inadequate if the bait station can be overturned.
- Recommended service frequency for bait stations is 7 days. Wet, caked, moldy, or otherwise out-of-condition bait must be changed. The active ingredient in bait is a rodenticide, not an insecticide, and old bait may become infested with insects.
- Use of bait inside facilities, although legal in covered bait stations, is not recommended due to possible accidental spillage of the poison.

Recommended bait for rats includes:

- All those recommended for mice.
- Fruits and vegetables such as fresh avocados, apples, celery, carrots, and raisins.
- Pieces of meat such as chicken skin or fish are good rat bait but must be changed daily.
- Fresh baits, as they may become infested with insects.

Other tips:

- Gloves need not be worn nor traps kept especially clean since rodents are used to human odors.
- Rat traps can be anchored vertically on beams or other overheads to kill roof rats or tied to fine wire and lowered into storm drains, freight elevator pits, or sewers.
- It is not necessary to number or map snap traps, since these are usually for direct control of temporary infestations.
- When using snap traps for rats, the traps should be placed in position and left for several days before baiting and setting. This is because rats, unlike mice, are suspicious of anything new in their environment and will avoid it for days.

Tracking Powders

Rodents ingest tracking powders when they groom and lick their fur. The current materials of choice are zinc phosphide or iandione, and we recommend that these only be used or exposed in spill-proof, tamper-resistant stations in nonfood zones.

Rat Burrow Fumigation

Active rat burrows on ditch banks, at wall bases, or alongside outbuildings can be gassed using US Environmental Protection Agency-registered fumigants so long as there is no risk of gas entering employee-occupied structures. Pellet or tablet formulations of aluminum phosphide are suitable if temperatures are above 40°F (4.4°C). In the US, all phosphine-generating fumigants are restricted-use pesticides, so users must be state certified. Cartridges which thermally generate sulfur or sulfur dioxide are general-use pesticides and may be used effectively for burrow treatments.

Recordkeeping and Reference Material

The individual responsible for the rodent control program should keep records or maintain a file to include:

- Sample labels and Material Safety Data Sheets of all rodenticides used.
- Pest control service records.
- Building and grounds plot maps should show the numerical designation and location of each bait station, Ketch-All, and glue board. Snap traps need not be listed.
- Keep logs of each and every service of rodent control tools, including date, technician's name, quantity and kind of bait put out, and number and kind of rodents trapped or found.
- Individual service tags on lids of bait stations and Ketch-Alls must be dated and signed by the technician.
- Service records provided by reputable contract pest control firms are suitable so long as information is complete and records are legible.
- Current license for pest control technician and/or company to practice.
- Current insurance certificate for pest control company.
- Subscription to one or two pest control industry periodicals.
- A file containing catalogs of pest control product suppliers.

Additional Information

Two classic, detailed references on this subject are:

Scott, H. G. and Borom, H. R. 1965. *Rodent-Borne Disease Control Through Rodent Stoppage*.

H. S. Public Health Service (CDC). 34 pages.
Peterson, G. M. 1978. *Rodent-Proof Design and Construction*. Waverly Press. 151 pages.

Basic Freezing

US Department of Agriculture, Food Safety and Inspection Service

Every year, the USDA Meat and Poultry Hotline receives thousands of calls from consumers about the safety of frozen food. The confusion is based on the fact that few people understand the freezing process. Here is some information on how to freeze food safely and how long to keep it.

What Can You Freeze?

You can freeze almost any foods. Some exceptions are cans of foods or eggs in shells. However, once the food (such as a ham) is out of the can, you may freeze it.

Being able to freeze food and being pleased with the quality after defrosting are two different things. Some foods simply don't freeze well at all. Examples are mayonnaise, cream sauce, and lettuce. Raw meat and poultry maintain their quality longer than their cooked counterparts because moisture is lost during cooking.

Is Frozen Food Safe?

Food stored constantly at 0°F (-18°C) will always be safe. Only the quality suffers with lengthy freezer storage. Freezing keeps food safe by slowing the movement of molecules, causing microbes to enter a dormant stage. Freezing preserves food for extended periods because it prevents the growth of microorganisms that cause both food spoilage and food borne illness.

Does Freezing Destroy Bacteria and Parasites?

Freezing to 0°F (-18°C) inactivates any microbes—bacteria, yeasts, and molds—present in food. Once thawed, however, these microbes can again become active, multiplying under the right conditions to levels that can lead to food borne illness. Since they will then grow at about the same rate as microorganisms on fresh food, you must handle thawed items as you would any perishable. Thorough cooking will destroy bacteria.

Trichina and other parasites can be destroyed by subzero (below 0°F or -18°C) freezing temperatures. However, very strict government-supervised conditions must be met. It is not recommended to rely on home freezing to destroy trichina. Thorough cooking will destroy all parasites.

Freshness and Quality

Freshness and quality at the time of freezing affect the condition of frozen foods. If frozen at peak quality, foods emerge tasting better than foods frozen near the end of their useful life. So freeze items you won't use quickly sooner rather than later. Store all foods at 0°F (-18°C) or

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lower to retain vitamin content, color, flavor, and texture.

Nutrient Retention

The freezing process itself does not destroy nutrients. In meat and poultry products, there is little change in nutrient value during freezer storage.

Enzymes

Enzyme activity can lead to the deterioration of food's quality. Enzymes present in animals, vegetables, and fruit promote chemical reactions, such as ripening. Freezing only slows the enzyme activity that takes place in foods. It does not halt these reactions which continue after harvesting. Enzyme activity does not harm frozen meats or fish and is neutralized by the acids in frozen fruits. But most vegetables that freeze well are low acid and require a brief, partial cooking to prevent deterioration. This is called "blanching." For successful freezing, blanch or partially cook vegetables in boiling water or in a microwave oven. Then rapidly chill the vegetables prior to freezing and storage. Consult a cookbook for timing.

Packaging

Proper packaging helps maintain quality and prevent "freezer burn." It is safe to freeze meat or poultry directly in its supermarket wrapping but this type of wrap is permeable to air. Unless you will be using the food in a month or two, overwrap these packages as you would any food for long-term storage using airtight heavy-duty foil, plastic wrap, or freezer paper, or place the package inside a plastic bag. Use these materials or airtight freezer containers to repackage family packs into smaller amounts or freeze foods from opened packages. It is not necessary to rinse meat and poultry before freezing. Freeze unopened vacuum packages as is. If you notice that a package has accidentally torn or has opened while food is in the freezer, it is still safe to use; merely overwrap or rewrap it.

Freezer Burn

Freezer burn does not make food unsafe, merely dry in spots. It appears as grayish-brown leathery spots and is caused by air reaching the surface of the food. Cut freezer-burned portions away either before or after cooking the food. Heavily freezer-burned foods may have to be discarded for quality reasons.

Color Changes

Color changes can occur in frozen foods. The bright red color of meat as purchased usually turns dark or pale brown depending on its variety. This may be due to lack of oxygen, freezer burn, or abnormally long storage.

Freezing doesn't usually cause color changes in poultry. However, the bones and the meat near them can become dark. Bone darkening results when pigment seeps through the porous bones of young poultry into the surrounding tissues when the poultry meat is frozen and thawed.

The dulling of color in frozen vegetables and cooked foods is usually the result of excessive drying due to improper packaging or over-lengthy storage.

Freeze Rapidly

Freeze food as fast as possible to maintain its quality. Rapid freezing prevents undesirable large ice crystals from forming throughout the product because the molecules don't have time to take their positions in the characteristic six-sided snowflake. Slow freezing creates large, disruptive ice crystals. During thawing, they damage the cells and dissolve emulsions. This causes meat to "drip"—lose juiciness. Emulsions such as mayonnaise or cream will separate and appear curdled. Ideally, a food 2 in. (5 cm) thick should freeze completely in about 2 hours. If your home freezer has a "quick-freeze" shelf, use it. Never stack packages to be frozen. Instead, spread them out in one layer on various shelves, stacking them only after frozen solid.

Refrigerator-Freezers

If a refrigerator freezing compartment can't maintain 0°F (-18°C) or if the door is opened frequently, use it for short-term food storage. Eat those foods as soon as possible for best quality. Use a free-standing freezer set at 0°F (-18°C) or below for long-term storage of frozen foods. And keep a thermometer in your freezing compartment or freezer to check the temperature.

Length of Time

Because freezing keeps food safe almost indefinitely, recommended storage times are for quality only. (Refer to the freezer storage chart at the end of this document for examples.) You can also determine quality after defrosting. First check the odor. Some foods will develop a rancid or off odor when frozen too long and should be discarded. Some may not look picture perfect or be of high enough quality to serve alone but may be edible: use them to make soups or stews. Cook raw food and if you like the taste and texture, use it.

Safe Defrosting

Never defrost foods in a garage, basement, car, dishwasher, or plastic garbage bag; out on the kitchen counter, outdoors, or on the porch. These methods can leave your foods unsafe to eat. There are three safe ways to defrost food: in the refrigerator, in cold water, or in the microwave. It's best to plan ahead for slow, safe thawing in the refrigerator. Small items may defrost overnight; most foods require a day or two. And large items like turkeys may take longer—one day for each 5 lbs. (2.3 kg) of weight.

For faster defrosting, place food in a leakproof plastic bag and immerse it in cold water. (If the bag leaks, bacteria from the air or surrounding environment could be introduced into the food. Tissues can also absorb water like a sponge, resulting in a watery product.) Check the water frequently to be sure it stays cold. Change the water every 30 minutes. After thawing, refrigerate the food until ready to use.

When microwave-defrosting food, plan to cook it immediately after thawing because some areas of the food may become warm and begin to cook during microwaving. Holding partially cooked food is not recommended because any bacteria present wouldn't have been destroyed.

Refreezing

Once food is thawed in the refrigerator, it is safe to refreeze it without cooking, although there may be a loss of quality due to the moisture lost through defrosting. After cooking raw foods which were previously frozen, it is safe to freeze the cooked foods. And if previously cooked foods are

thawed in the refrigerator, you may refreeze the unused portion. If you purchase previously frozen meat, poultry, or fish at a retail store, you can refreeze if it has been handled properly.

Cooking Frozen Foods

Raw or cooked meat, poultry, or casseroles can be cooked or reheated from the frozen state. However, it will take approximately one and a half times the usual cooking time for food which has been thawed. Remember to discard any wrapping or absorbent paper from meat or poultry. When cooking whole poultry, remove the giblet pack from the cavity as soon as you can loosen it. Cook the giblets separately. Read the label on USDA-inspected frozen meat and poultry products. Some, such as pre-stuffed whole birds, must be cooked from the frozen state to ensure a safely cooked product.

Power Outage in Freezer

If there is a power outage, the freezer fails, or the freezer door has been left ajar by mistake, the food may still be safe to use. As long as a freezer with its door ajar is continuing to cool, the foods should stay safe overnight. If a repairman is on the way or it appears the power will be on soon, just don't open the freezer door.

A freezer full of food will usually keep about 2 days if the door is kept shut; a half-full freezer will last about a day. The freezing compartment in a refrigerator may not keep foods frozen as long. If the freezer is not full, quickly group packages together so they will retain the cold more effectively. Separate meat and poultry items from other foods so if they begin to thaw, their juices won't drip onto other foods.

For short term power outages—less than 6 hours—leave the door closed until the power returns. If the power is off for more than 6 hours, you may want to put dry ice, block ice, or bags of ice in the freezer, or transfer foods to a friend's freezer until power is restored. Use an appliance thermometer to monitor the temperature.

If it's freezing outside or if there's snow on the ground, that might seem like a good place to keep food frozen until the power comes on. However, foods stored in the great outdoors are exposed to the sun, environmental contamination, roaming animals, and birds. So keep food indoors.

To determine the safety of foods when the power goes on, check their condition and temperature. If food is partly frozen, still has ice crystals, or is as cold as if it were in a refrigerator (40°F = 4.4°C), it is safe to refreeze or use. It's not necessary to cook raw foods before refreezing. *Discard foods that have been warmer than 40°F (4.4°C) for more than 2 hours. Discard any foods that have been contaminated by raw meat juices. Dispose of soft or melted ice cream for quality's sake.*

Frozen Cans

Accidentally frozen cans, such as those left in a car or basement in temperatures below 0°F (-18°C), can present health problems. If the cans are merely swollen—and you are sure the swelling was caused by freezing—the cans may still be usable. Let the can thaw in the refrigerator before opening. If the product doesn't look and/or smell normal, throw it out. Do not taste it! However, if the product does look and/or smell normal, thoroughly cook the contents by boiling for 10 to 20 minutes right away. But if the seams have rusted or burst, throw the cans out immediately.

Frozen Eggs

Shell eggs should not be frozen. If an egg accidentally freezes and the shell cracks during freezing, discard the egg. Keep an uncracked egg frozen until needed; then thaw in the refrigerator. It can be hard cooked successfully but other uses may be limited. That's because freezing causes the yolk to become thick and syrupy so it will not flow like an unfrozen yolk or blend very well with the egg white or other ingredients.

Freezer Storage Chart (0°F or -18°C)

Note: Freezer storage life is for quality only. Frozen foods remain safe indefinitely.

Item	Freezer storage life
Bacon and sausage	1-2 months
Casseroles	1-2 months
Eggs whites or egg substitutes	12 months
Gravy, meat, or poultry	2-3 months
Ham, hotdogs, and lunchmeats	1-2 months
Meat, uncooked roasts	9 months
Meat, uncooked steaks or chops	4-6 months
Meat, uncooked ground	3-4 months
Meat, cooked	2-3 months
Poultry, uncooked whole	12 months
Poultry, uncooked parts	9 months
Poultry, uncooked giblets	3-4 months
Poultry, cooked	3-4 months
Soups and stews	2-3 months
Wild game, uncooked	8-12 months

Food Preservation—Product, Process, and Packaging

Donald V. Schlimme

Introduction

The principal benefit of refrigeration as it is relevant to the public refrigerated warehouse industry is related to its food preservation effects. Food preservation is the conversion of raw materials into intermediate foodstuffs or edible products through the application of labor, machinery, energy, and scientific knowledge. This conversion is often referred to as food processing. Ultimately, food preservation is the use of operations designed to extend the shelf life of foods by reducing or eliminating microbe activity and degradative chemical reactions. The shelf life of a food product is defined as the maximum time between its manufacture and its attainment of unacceptability to a discerning consumer.

Food Quality Factors

All foods, regardless of the type of preservation operations employed, eventually undergo degradation of color, flavor, texture, and nutrient status. Once a food is preserved and packaged it is not stable forever. Each food system slowly decays or deteriorates to the point where it is unacceptable to discerning consumers. This ultimate loss of acceptability does not necessarily mean the product is inedible, but only that the established consumer quality minimum standard has been passed.

The important factors that influence the point in time when the established consumer quality minimum standard has been attained are:

I. Intrinsic Factors of the Food
   - The amount of lipid present (especially unsaturated fats)
   - The nature of the pigments present
   - The moisture content
   - The initial nutrient level present
   - The water activity (Aw)
   - The pH
   - The oxygen level
   - The kind and amount of preservatives present

II. Packaging Characteristics
   - The permeability of the package to gases such as oxygen, carbon dioxide, and moisture vapor
   - Seal integrity
   - The degree of chemical reactivity of the package material
   - The light transmission potential
   - The nature of the internal package atmosphere in terms of oxygen, carbon dioxide, and nitrogen levels

III. Environmental Characteristics During Storage, Distribution, and Marketing
- Temperature
- Relative humidity

Methods of Preservation

There are many modes of food preservation currently used in the modern world, including temperature elevation, temperature reduction, water content reduction and reduction of water activity, ionizing radiation, fermentation, and smoking. These food preservation methods accomplish one or more of the following functions or goals:

1. Retard quality degradation
2. Minimize/eliminate microbial spoilage
3. Promote microbial food safety
4. Extend product shelf life
5. Minimize product moisture loss
6. Minimize deterioration due to chemical reactions
7. Minimize/eliminate damage caused by pests

Although there are advantages and disadvantages associated with each of the foregoing modes of food preservation, each attempts to achieve some, if not all, of these seven goals.

Temperature Elevation

Preservation by temperature elevation is called blanching, pasteurization, and canning. The primary goal of temperature elevation preservation is the reduction or elimination of microbial life forms and the destruction of enzyme systems in the food. Pasteurized foods usually require refrigerated storage, distribution, and marketing to achieve a commercially viable shelf life. Canned foods are usually commercially sterile and require no refrigeration in order to achieve a shelf life ranging from 6 to 36 months at ambient temperature. Canning and, to a lesser extent, pasteurization often cause product quality loss due to elevated temperature induced changes; canning does provide a long, ambient temperature shelf life and freedom from pathogenic and spoilage microbes.

Water Reduction

Preservation by water content reduction or by decreasing the water activity of the food is called dehydration, drying, baking, and salting. The primary goal of water content reduction food preservation is a reduction in the number of microbes present and, more importantly, establishing a condition where microbial life forms cannot grow. Water content reduction also often causes a reduction in the rate of some degradative chemical reactions. Preservation by lowering water activity and/or increasing salt content has as a primary goal the prevention of microbial growth. The advantage of these modes of preservation is a relatively long shelf life at ambient temperature. Disadvantages include a significant degradation of product flavor, color, and especially textural quality.

Ionizing Radiation

The use of ionizing radiation to preserve food aims to reduce or eliminate microbes. Low dose irradiation can markedly lower microbe count on foods, but it does not sterilize the food. Low

dose irradiation of fresh or fresh-like foods is often employed in conjunction with refrigeration and refrigerated storage and distribution to achieve a commercially viable shelf life. High dose irradiation can provide for commercial sterility, but usually the food must be packaged and frozen before it is irradiated. Subsequent storage and distribution can be at ambient temperature to achieve a moderately long shelf life. The advantage of food irradiation is its potential to either drastically reduce the population of pathogenic and food spoilage microbes or to eliminate them entirely without causing undue reduction in product quality. Major disadvantages of irradiation preservation are its potential to cause off-flavors and consumer perceptions that irradiated foods are somehow unsafe for consumption.

Temperature Reduction

Food preservation by temperature reduction is usually called chilling, refrigeration, or freezing. Refrigerated foods have product temperatures below ambient but above their freezing points during distribution and storage. These chilled foods typically have temperatures as low as 31-32°F (-0.6 to 0°C), which extend product shelf life primarily as a result of delayed growth of microbes. A major secondary benefit of chilling temperatures is a slowing of the rate of respiration and catabolic metabolism of fresh produce. Chilled foods often have "like-fresh" quality but, in most cases, experience only limited shelf life extension as compared to foods preserved by other methods.

Frozen foods have product temperatures below the freezing point of water within the food. Thus, food freezing results in the formation of ice within the food. The temperature at which ice begins to form within food varies according to intrinsic characteristics of the food such as its percentage of free (unbound) water and its ratio of water content to the content of water-soluble materials present. For the majority of food products, the temperature at which ice begins to form ranges from slightly less than 32°F (0°C) to about 28°F (-2.2°C). When water in food is transformed to ice it becomes unavailable for microbe use. Once the food temperature is lowered to about 15-20°F (-9.4 to -6.7°C), microbial growth is essentially terminated because the minimum temperature to support it has been exceeded. Thus, freezing food essentially terminates microbial growth by both temperature reduction and by eliminating water activity. Freezing food usually results in a slight to moderate reduction in the number of viable microbes present, but substantial numbers of microbes remain viable in a dormant state. The dormant microbes can resume growth when the food is thawed to above freezing temperature.

Quality in Frozen Foods

Ice crystals begin to form in the food when its temperature is reduced to just below its freezing point. If the food being frozen is a solid (a fish fillet, for example) rather than a liquid (orange juice concentrate, for example), ice crystals form between the tissue cells and cause disruption of cell structure, which results in alteration of the texture of the food material. Ice crystal size is reduced and tissue disruption is lessened when a very rapid freezing rate is achieved. Sometimes ice crystal induced disruption is extremely detrimental to the textural quality of the food (whole tomatoes or tomato slices or hard cooked eggs, for example) and sometimes it is beneficial for textural quality, such as for tenderizing a tough cut of meat. In some cases the formation of ice crystals has an almost neutral effect on textural quality (poultry, for example).

The effect of freezing on flavor, color, and nutritional quality of foods is nearly negligible, and many foods that have just been rapidly frozen are "fresh-like" in sensory quality upon thawing. Frozen foods undergo less degradation of flavor, color, and nutritional characteristics than do

similar foods preserved by pasteurization, canning, and dehydration and retain their sensory and nutritional quality advantage for moderately long periods of storage. Nevertheless, frozen food sensory and nutritional quality declines during frozen storage. The rate of change varies substantially depending upon intrinsic, packaging, and environmental characteristics present during storage.

Food product texture is the quality attribute most likely to be influenced by the freezing process. Other quality attributes of frozen foods are far more influenced by conditions maintained during frozen storage than by the freezing process. Thus, the quality of a frozen food at the time it is consumed is very strongly influenced by storage conditions and, of course, storage duration.

Effect of Temperature

Quality changes that occur after freezing and during post-freezing storage are highly correlated with storage temperature and the nature of the food's packaging. If the temperature of the food is maintained at about 10°F (-12.2°C) or less, there is negligible microbial activity and microbial spoilage is nil. However, enzymatic and nonenzymatic chemical reactions resulting in pigment degradation, vitamin loss, lipid oxidation, and browning occur in frozen foods even at the recommended storage temperature of 0°F (-18°C), albeit it at a relatively slow rate. These degradative changes in quality decrease as storage temperature decreases until change becomes negligible when storage temperature attains -100°F (-73.3°C). But maintaining frozen food storage temperature at such a low level results in prohibitively high storage costs. Thus, experience has established that frozen food storage at 0°F (-18°C) is satisfactory for maintaining adequate shelf life for most frozen foods.

It is useful to evaluate the influence of storage temperature on enzymatic and nonenzymatic chemical reaction rates in order to better understand and appreciate its effect on food shelf life. It has long been known that the rate of many chemical reactions is increased by a factor of 2-3 when the temperature of the reactant mixture is increased by 18°F (10°C). Conversely, reaction rate is reduced 2-3 fold when the temperature is lowered by 18°F (10°C). The general effect of increased temperature on chemical reaction rate is referred to as "the temperature accelerating effect" and is often expressed by the symbol "Q10." The changes in quality that occur during food storage are, in large measure, a consequence of chemical reactions such as oxidation, disulfide cross-linking, hydrolysis, and deamination. These chemical changes often result in quality loss, and each has its own Q10 value. A useful example of the effect of storage temperature on food quality, and therefore upon its shelf life, is an inspection of the effect of temperature on lipid oxidation and nonenzymatic browning rates in dehydrated potatoes:

Storage Temperature		% of Total Lipids	Acceptable Shelf	% Lipid Oxidized	Q10
(°F)	(°C)	Oxidized	Life in Days	per day	Value
32	0	7	~800	0.00875	—
50	10	7	~580	0.0121	1.38
68	20	7	~430	0.0163	1.35
86	30	7	~300	0.023	1.41
104	40	7	~250	0.028	1.22
122	50	7	~180	0.039	1.39

The shelf life in days of dehydrated potatoes at various storage temperatures when quality degradation due to nonenzymatic browning (tissue darkening) is measured:

Storage Temperature (°F)	(°C)	L Value Decrease	Acceptable Shelf Life in Days	Decrease in L Value per Day	Q10 Value
86	30	40	~500	0.08	—
104	40	40	80	0.50	6.25
122	50	40	8	5.00	10.00

It is apparent from the above tables that Q10 values for lipid oxidation of dehydrated potatoes are less than 2 across the storage temperature range of 0-50°C (32-122°F). Furthermore, each 10°C (18°F) incremental temperature change has only a modest effect on the duration of acceptable shelf life. On the other hand, Q10 values for nonenzymatic browning are quite large (6.25-10) across the storage temperature range of 30-50°C (86-122°F). Within this temperature range, 10°C (18°F) incremental temperature changes have a great effect on the duration of acceptable shelf life.

Since many chemical changes occur in foods during storage and each change has a different Q10 value, the end point of shelf life varies according to which chemical change is being monitored. Of course, the end of shelf life point for a given food is selected according to which has the greatest effect on consumer acceptability. According to the above data, if dehydrated potatoes were stored at 30°C (86°F) for 300 days, shelf life would end due to excessive lipid oxidation. This would produce an unacceptable level of rancid off-flavor. But it would take 500 days of storage at 30°C (86°F) before the product would be unacceptable due to darkening of the potatoes (as measured by a color meter Hunter L value decrease of 40 units, e.g., from 90 to 50). Hunter color meter L value is an analytical measure of lightness/darkness of an object.

An example of the degradation of quality attributes during frozen storage at 0°F (-18°C) is illustrated by considering some of the changes that can occur in a packaged frozen sausage pizza. The major problems that occur during frozen storage of this product are:

1. Moisture loss from the pizza to the in-package atmosphere and ice crystal formation on the inside surface of the package
2. Development of off/rancid flavors due to enzymatic oxidation of lipids in the crust, cheese, and sausage
3. Loss of red tomato sauce color due to chemical degradation to lycopene pigments
4. Loss of spice flavor intensity
5. Development of crust sogginess or loss of crust crispness

Each of these changes has a negative impact on sensory quality and, therefore, each causes a decrease in shelf life. Q10 values for frozen food quality changes vary from 3 to 40. Thus, rather modest temperature abuse can dramatically shorten acceptable shelf life in frozen foods as can excessive cycling of the storage temperature.

Effect of Packaging

Control of storage temperature at a low, uniform temperature is essential for minimizing the formation of ice crystals in the head space inside the food package. Minimizing looseness of the package by making it fit as tightly as possible around the food will minimize the head space inside the package. Such packaging of frozen foods (using good moisture barrier materials) helps to minimize moisture loss and freezer burn. If the food is vacuum packaged using a good oxygen barrier packaging material, oxidative chemical reactions can be reduced. If a high gas

barrier packaging material is used, odor transfer from other items in the same storage area to the food can be minimized.

Conclusion

The nature of the product (Product factors), the type of freezing process used (Process factors), and the nature of the packaging used (Packaging factors) all have a profound effect on the magnitude of the shelf life of frozen foods. In addition to these PPP factors, which warehouse operators have little control over, the post-freezing process storage environment also has a substantial effect on frozen food storage life and quality. *Adequately low temperature, minimal temperature cycling, and absence of temperature abuse all contribute greatly to quality maintenance. It is important to recognize that adequate frozen and refrigerated food shelf life is linked not only to PPP factors but also to the inputs and stewardship of warehousing professionals.*

Opportunities in Using Biotechnology to Maintain Postharvest Quality and Safety of Fresh Produce

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The primary goals of research on postharvest biology and technology of fresh produce are to reduce losses in quantity and quality between harvest and consumption. The strategies for attaining these goals include selection of genotypes with good sensory quality when harvested at optimum maturity, use of an integrated crop management system that maximizes yield without sacrificing quality, and use of optimum postharvest handling procedures to maintain the quality and safety of the produce. Providing consumers with fruits and vegetables that taste good can greatly encourage their consumption of the recommended minimum of five servings per day for better health. The most useful technological changes in the production, harvesting, and postharvest handling systems for horticultural crops have resulted from interdisciplinary research and development approaches and this is likely to continue to be true in the future. Thus, biotechnology is a tool that can be utilized in an interdisciplinary approach, to address some of the concerns about quality attributes and the biological causes of deterioration of harvested produce. In this brief overview, I will provide some examples of the opportunities and limitations in using biotechnology to maintain postharvest quality and safety of fresh produce.

Composition and appearance quality. Color is a very important appearance quality factor that is related to biosynthesis and degradation of pigments, including chlorophylls, carotenoids, and flavonoids. Biotechnology can be used to improve color uniformity and intensity and to minimize undesirable colors, such as browning. Tissue browning is dependent upon the concentration of phenolic compounds, the activity of polyphenol oxidase (PPO), and the concentration of antioxidants. These factors can be manipulated to produce genotypes with low browning potential, which is a very useful trait in many commodities when marketed intact or as fresh-cut products. The feasibility of such approach has been shown in potatoes with blocked PPO synthesis.

Composition and textural quality. Genetic manipulations to reduce the rate of lignification (toughening) of vegetables, such as asparagus and green beans, can be very useful in maintaining their textural Received for publication 29 Nov. 2001. Accepted for publication 30 Nov. 2001. quality. Another use for biotechnology is to reduce the rate of fruit softening to maintain their firmness and minimize physical damage throughout the postharvest handling system. This can be achieved by altering cell wall metabolism in all fruits and/or ethylene biosynthesis and action in climacteric fruits, as has been demonstrated in tomatoes.

Composition and flavor quality. Flavor quality factors include sweetness (kinds and quantity of sugars), sourness or acidity (kinds and quantity of acids), astringency (phenolic compounds), and aroma or odor (volatile compounds). The relative importance of each of these factors and their interactions depends upon the commodity. The greatest need is to produce new fruit genotypes with better flavor, which means high sugars (or greater proportion of fructose and/or sucrose than glucose)

and moderate to high acids (with balance between them), low phenolics, and enough of the organoleptically important volatiles for good aroma. Since flavor quality involves perception of the tastes and aromas of many compounds, it is much more challenging to manipulate than other quality factors. This has been true for plant breeders in the past and it will continue to be so with biotechnology approaches. This may be the reason that improvement of flavor quality has received much less attention from biotechnologists so far than textural quality of fruits.

Composition and nutritional quality. Plant breeders have been successful in selecting genotypes with much higher contents of ascorbic acid (vitamin C) in guava and tomatoes, beta carotene (provitamin A) in carrots and tomatoes, and flavonoids in berries. Biotechnology approaches can be utilized to improve the content of vitamins, minerals, dietary fiber, and phytonutrients in fruits and vegetables, especially those with high per capita consumption rates. Phytonutrients that can lower the risk of heart disease, cancer, and other diseases include carotenoids, flavonoids (anthocyanins, phenolic acids, polyphenols), isoflavones, phytosterols, and organosulfur compounds. The antioxidant capacity of fruits, nuts, and vegetables is related to their contents of anthocyanins, phenolic compounds, carotenoids, ascorbic acid, and vitamin E. Large genotypic variations in total antioxidant capacity have been shown in many commodities, indicating the potential for further improvements using biotechnology. Another opportunity for use of biotechnology is to alter the fatty acids composition of some nuts to reduce their content of saturated fatty acids.

Rates of respiration and ethylene production. In many commodities we find an association between their postharvest life (rate of deterioration) and their rates of respiration and ethylene production. Selecting genotypes with lower rates of respiration and ethylene production is likely to result in lower rates of deterioration and longer postharvest life potential. However, in cases when ethylene production is largely inhibited in fruits, their volatile production is also inhibited, which has a negative impact on their aroma quality. The challenge is to separate the effects of genetic manipulation on ethylene biosynthesis from those on biosynthesis of esters and other desirable aroma volatiles.

Susceptibility to physiological disorders. Many physiological disorders have been identified and associated with exposure to undesirable temperatures, with low calcium levels, with O2, CO2, and/or C2H4 concentrations beyond those tolerated by the fruit, or with other factors. However, the physiological and biochemical basis of most of these disorders remains largely unknown. Thus, physiologists and biochemists need to identify the specific targets for biotechnological manipulation before biotechnology can be used to address these problems. Genotypic differences in susceptibility to chilling injury have been shown in most chilling-sensitive commodities. Thus, it should be possible to use biotechnology to produce cultivars with lower chilling sensitivity to allow their handling at lower temperatures to extend their postharvest life. This is especially critical for tropical and subtropical commodities and for some temperate fruits that have low-temperature disorders, such as internal breakdown of stone fruits and scald of apples and pears. Another opportunity for biotechnology is to produce cultivars of nonfruit vegetables, such as broccoli and lettuce and flowers that are less susceptible to ethylene action. However, it is advisable to evaluate the feasibility and cost/benefit analysis of this approach in comparison with currently available treatments with 1-methylcyclopropene to inhibit ethylene action.

Susceptibility to pathological breakdown. One of the most common and obvious symptoms of deterioration results from the activity of fungi. Attack by most organisms follows physical injury or physiological breakdown of the commodity. In a few cases, pathogens can infect apparently

healthy tissues and become the primary cause of deterioration. In general, harvested fruits exhibit considerable resistance to potential pathogens during most of their postharvest life. The onset of ripening in fruits results in their becoming susceptible to infection by pathogens. There is an association between phenolic content in many commodities and their susceptibility to decay-causing pathogens. However, the challenge to biotechnological approaches is to maintain a balance between the desirable concentrations of phenolic compounds for resistance to pathogens and the undesirable levels in terms of astringency and/or browning potential. Another approach is to introduce polygalacturonase inhibitors and/or to increase the level of endogenous antifungal compounds without negative effects on quality and safety of the commodity.

Safety considerations. Minimizing chemical and microbial contamination during production, harvesting, and postharvest handling of fruits and vegetables is essential to assuring their safety to the consumer. Research and development efforts must continue to define optimum procedures for avoiding contamination with mycotoxins, heavy metals, and microorganisms during handling of fresh fruits and vegetables and their products. It may be possible to use biotechnology to alter the morphological structure of the surface of some commodities to minimize the areas in which human pathogens can be protected from washing and disinfection treatments.

Conclusions. It is clear that there are numerous opportunities in using biotechnology to maintain postharvest quality and safety of fresh produce. Thus, priorities for each commodity should be established on the basis of the relative importance of its postharvest deterioration causes and what is needed to encourage increased consumption. Overall, priority should be given to the following three goals:

- To attain and maintain good flavor and nutritional quality to meet consumer demands and encourage greater consumption of fresh fruits and vegetables.

- To introduce resistance to physiological disorders and/or decay-causing pathogens to reduce use of chemicals.

- To modify surface structure and/or composition of some commodities to reduce their microbial contamination potential.

The keys to success in maintaining quality and safety of biotechnologically produced genotypes of flowers, fruits, and vegetables are the same as those currently recommended, i.e., optimum maturity at harvest, careful and expedited handling, maintenance of optimum ranges of temperature and relative humidity, and minimizing chemical and microbiological contamination throughout the postharvest handling system. It is possible that new genotypes will void the need for some supplemental treatments to the commodity or its environment, but it is not likely that the need for paying attention to all the details of the above-mentioned keys to successful handling will be reduced.

Toxic Metals in Foods: Safety and Regulatory Issues

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1.0 Introduction:

Food safety is an essential public health issue for all the countries. Food borne diseases due to microbial pathogens, bio toxins and chemical contaminants in foods represent serious threats to the consumers which not only affect their health but also lead to economic losses. These diseases impose a substantial burden on healthcare systems and markedly affect productivity.

The integration and consolidation of food industries and the globalisation of the food trades are changing the patterns of food production, food processing, transportation, storage and distribution. Therefore, food safety programmes are being increasingly focused on a farm to table approach as an effective means of reducing food borne hazards. This holistic approach to the control of food related risks involves consideration of every step in the chain, from raw materials to food consumption.

Food contaminants that pose risk to the human health and therefore must be regulated are defined as the substances that are present in foods unintentionally as a result of production, manufacture, processing, preparation, treatment, packing, packaging, transport, or holding of such food or as a result of environmental contamination. The term doses not include insect fragments, rodent hairs and other such extraneous matter.

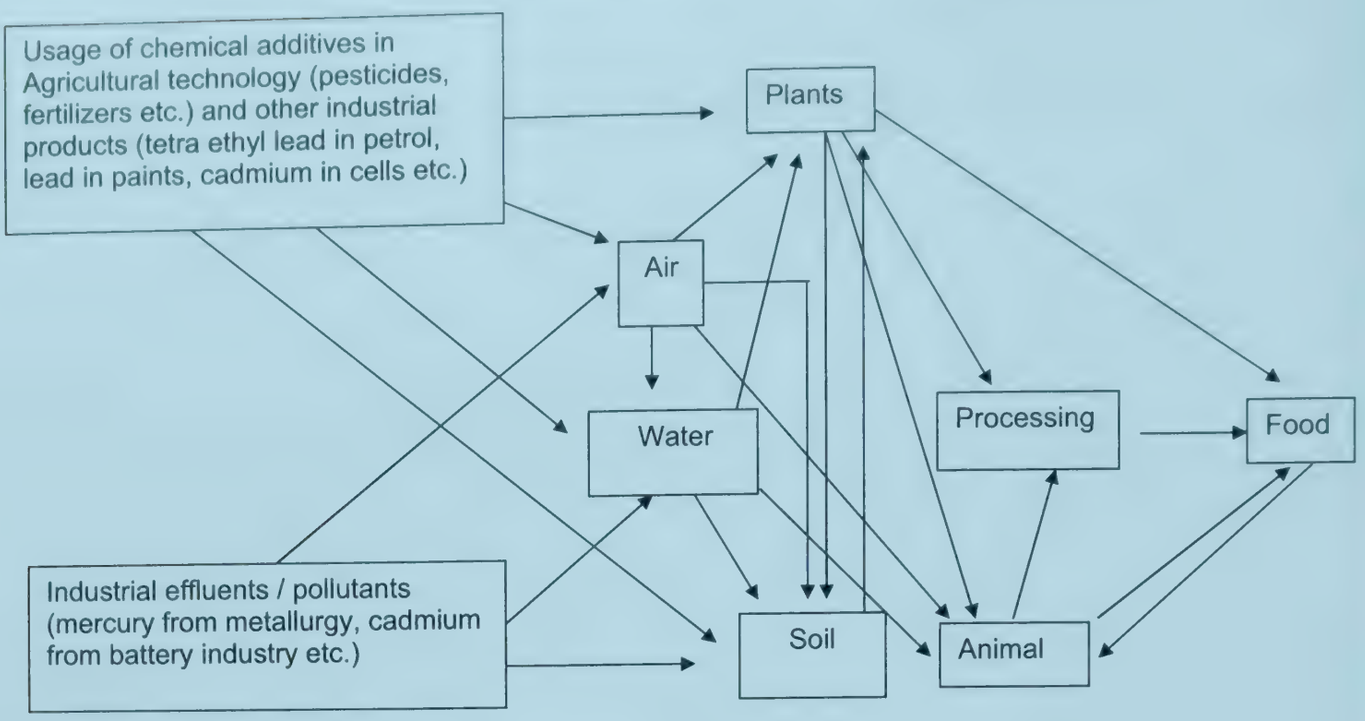
2.0 Metallic Contaminants:

A metal is an inorganic substance that is widely spread in nature. Many are found in soil and effluents and therefore easily enter the food chain. Many of these, such as Ca, Mg, Zn, Fe, Co, Ni, Cr and Mn are essential components of biological systems popularly referred to as micro-nutrients. Within cells, they mediate oxygen transport and metabolism catalyse electron transfer reaction, are involved in signal transduction processes and establish functional structures of macro molecules. There are metals which exhibit carcinogenicity and toxic properties. As, Pb, Cd, Be, and Ni, Co and Cr at higher concentrations are carcinogenic. A Change in concentration of a few order of magnitude of transitional elements will make the essential into a toxic metal. Thpese metals exhibit strong attraction to biological tissues and their elimination will be slow. When the physiological limits of excretion or disposal from system is crossed, these toxicants are retained in the body. Hazards and sources of pollution are given the following table:

The metals, which, in their standard state, have a specific gravity of more than about 5 g/cm^3 are referred to as heavy metals. Copper, iron, nickel are oxidation catalysts and at quite low levels of 0.1 mg/kg can lead to quality problems with fats and edible oils. Copper and copper alloys shall be excluded from any plant processing fatty products.

Metals normally enter the food chain through soil, air, and water as depicted in the following figure:

Figure 1. Entry of Toxic metals into Food



Toxic metal	Hazards	Sources of pollution
1. Lead	Anemia, Bone disorders, Neuro toxicity, Edema, Encephalopathy	Lead pipes, tetra ethyl lead (TEL from petrol), Solders, Bullets, Battery burning, Paints, Glass manufacturing etc
2. Cadmium	Kidney damage, Hyper tension, Lung edema, Gastro-intestinal disorders, Bone disorders. (Itai- Itai disease in Japan)	Batteries (Ni -Cd cells), Metal coatings, Pigments, Cd- vapour lamps, Plastics.
3. Mercury	Neurotoxicity, Encephalopathy, Stomatitis, Kidney damage (Bay Minamata disease in Japan)	Air- conditioner filters, Fungicides and Rodent poisons, Dental amalgam, Antiseptic creams & ointments, Fish & shell fish
4. Arsenic	Scaling and pigmentation of skin, poor memory / delirium, anemia, Lung and skin cancer, Accumulation in hair, nails & skin	Insecticides (Arsenates), Weed killers, Fungicides, War gases
4. Arsenic	Scaling and pigmentation of skin, poor memory / delirium, anemia, Lung and skin cancer, Accumulation in hair, nails & skin	Insecticides (Arsenates), Weed killers, Fungicides, War gases

Discharge of gaseous, liquid and solid waste from Different industries and their pollutant elements

INDUSTRY	TYPICAL POLLUTANT ELEMENTS
Power plant (coal, oil gas)	As, Be, Hg, Ni, Sb, Se
Oil refineries	As, Hg, Ni, Sb, Se
Gold mining and processing	Hg
Non-ferrous metal mining and processing	Al, Cd, Cu, F, Pb, Sn, Zn
Smelters	As, Ni, Sb, Se, Cd, Cr, Cu, Pb, Zn
Fertilizer plants	As, Cd, Sr, rare earth elements
Leather industries (tanneries)	Cr
Pesticide and herbicides	As, Br, Hg, Cd, Cl, Cu, Zn
Paper and pulp industry	Cl, Na, Zn, Hg
Electroplating industry	Co, Cr, Ni
Cement plant	Al, Ca, Cr, F, Tl

The food processing industry in developing countries ranges from sophisticated state-of-the-art facilities to small artisanal operations producing traditional food for the local community. The size of these processing units is quite variable from a few large plants to a majority of small and cottage scale units with very limited resources for effective technological inputs. At the least developed end of this continuum, these premises are ill equipped to deal with the maintenance of food safety and quality in a scientific and sustained manner. Also, there is a problem with reliability and timely delivery of raw materials and variations in their quality. Therefore, food processing units may have to exercise greater vigil at all stages along the food supply chain. Added to this is street foods on which some segments of population is entirely dependant as they are affordable.

Product quality, health and sanitation issues are major concern in the food-processing industry. Maintenance management systems are implemented in food-processing plants to monitor machine production histories, downtime, and reliability to prioritise equipment and maintenance problems. Reliability based maintenance teams are used in conjunction with maintenance management systems to predict maintenance needs and conduct root-cause analyses of food-processing failures. In the food processing industry as quality is the key issue, corrosion products are not acceptable in the food products due to health reasons.

3.0 Metallic food contact materials:

Stainless steels are the important food contact materials in food and beverage industries. They are applied in various segments such as: transportation(milk carriages); processing equipment mainly for dairy and chocolate industries; processing of fruits; for wine, for brew kettles and beer kegs; for processing of dry foods such as cereals, flour and sugar; for utensils such as blenders, bread dough mixers; in slaughter houses; in processing of fish etc. Stainless steels are also important in domestic food contact applications such as electric kettles, kitchen-ware and kitchen fittings such as sinks, counters and drains; for bowls, knives, spoons and forks. This extremely wide usage is due to the fact that stainless steels resist corrosion by foods and beverages, and they are readily cleaned, thereby providing hygiene in food processing and handling. No flavours or discolouration are imparted.

ASTM grades 304 and 316 find extensive application in food processing equipment.

4.0 Heavy metal migration from food machinery:

Stainless steels are so called because they are resistant to corrosion in conditions under which iron or non-stainless steels would rust or corrode. Foods are dynamic in nature, that is, they react intimately with food contact materials thereby leaching some metals or additives used in the stainless steel. However, chromium that is added to steels in the range of 10.5% to 17% or 20% to form a passive film in contact with oxygen in air or moisture acts as protective barrier to corrosion. It promotes passivation and molybdenum is very effective in stabilizing the film in presence of chlorides. Small amounts of lead, cadmium, aluminium, nickel, chromium, copper, zinc, tin, and iron may migrate into foodstuffs from food processing and cooking equipment leading to human ingestion thereby posing health risks which have to be addressed in safety issues.

Metallic foreign bodies must be detected and removed from all foods; metals in raw materials shall be removed as far as possible before processing. Techniques for detecting and removing metals include magnets, metal detectors and x-ray scanners.

Magnets are used in removing iron filings from processed tea. A new USDA method for detecting metallic contaminants in meat products based on monitoring the electrical resistance between components of a chopping machine is available (Dixon J M, 1983).The resistance significantly decreases if metals are present in the products.

Today, the analytical techniques have made it possible to detect the toxic metals at ppb or ppt levels which has enabled the toxicologists, in animal experiments, to follow up the effects of individual substances down to the smallest concentrations.

There are about 60 heavy metals which include precious metals such as platinum, silver and gold. From food contamination point of view, however, only small group of heavy metals is of significance. Some aspects of heavy/toxic metals such as Occurrence in foods, Migration from food contact materials such as processing equipment, Safety and Regulatory issues will be discussed (C.E., 2002).

5.1 Cadmium: Cadmium is a metal of most health concern in food. Phosphate fertilizers and sewage sludge used on agricultural land may be the significant source of cadmium. In foods, cadmium is found in the range of 0.005-0.1 mg/kg (Friberg et al.1986); mushrooms, crustaceans, offal, shellfish, some fungi, and oysters contain high concentrations of cadmium. Rice and wheat are also reported to contain high amounts of cadmium. In food contact applications, cadmium is mainly used as an anticorrosive electroplate on steel (Friberg et al 1986); it is present as an impurity in zinc galvanized pipes and in solders. Cadmium sulphide and selenide have been used as pigments in plastics, paints and enamels in food contact materials. Leachable cadmium in enamel pottery and glazes may be a source of contamination. The migration of cadmium from processing machinery to foods is limited. Cadmium loses its luster in moist air and is rapidly corroded by moist ammonia and sulphur dioxide. It is readily attacked by most acids.(Beliles, 1994).

Safety aspects:

- JECFA in 1993 has established a PTWI of 0.007 mg/kg. b.wt.
- SCF has acknowledged the carcinogenic risk of cadmium from dietary exposure.
- Average ingested amount of cadmium in Europe is 0.01-0.02 mg/day.

- Cadmium has toxicity in low dosage and has long biologic half life(30 years),
- Low rate of excretion and stored predominantly in soft tissues(liver and kidney) (Bellier1994); effects on human are nephrotoxicity, osteotoxicity, cardiovascular toxicity effects
- effects on reproduction and development and genotoxicity (E.C. 1996).
- Itai-itai disease in Japan was traced to cadmium in rice.

Therefore, the use of cadmium in food contact materials is unacceptable and regulatory agencies have prohibited its use (e.g., EU directive 91/338/EEC).

5.2 Mercury: Organic mercury is of more concern from health risk point of view. The burning of fossil fuel, the smelting of sulfide ores, and other activities release about 100 tons of mercury into global environment every year(Florence and Batley, 1980). Methyl mercury is biosynthesized from inorganic mercury through microbial activity (ASTDR, 1997). Methyl mercury is found in fish and seafood. In foodstuffs, mercury is found in concentrations ranging from 0.005-0.05 mg/kg. No information is available regarding the migration of mercury from food contact materials. However, other sources of mercury in foods are paints and agro chemicals.

Safety aspects:

- JECFA in 1988 has established PTWI of 0.005 mg/kg b.wt. and max. of 0.0033 for methyl mercury
- Average daily intake is 0.002-0.02 mg.(mainly from fish; Codex 1995)
- The toxic properties are due to the accumulation in the brain causing neurological effects involving an unspecific psychoasthenic and vegetative syndrome (micro mercurialism) (Berlin, 1986). At high exposure levels, mercurial tremor is seen accompanied by severe behavioural and personality changes, increased excitability, loss of memory and insomnia.(Berlin, 1986). Methyl mercury is listed as one of the six most dangerous chemicals in environment. Teratogenic effects observed.

Therefore, use of mercury in all food application is prohibited.

5.3 Lead: Vegetables contain lead up to 0.05 mg/kg(NFA Denmark, 1995). Cereals and cereal products up to 0.09 mg/kg; fruit and fruit juice, wines, beverages, and drinking water up to 0.05 mg/kg.(Codex, 1995).

Metallic food contact materials: Lead soldering is not resorted to in the modern food canning industry. However, in some parts still lead soldered cans are being used. Lead is also found in lead solder used to repair the equipment and soldered closures of condensed milk cans and metal caps of wine bottles. Previously lead pigments were used in ceramic glazes (Beliles, 1994). Use of toxic lead pigments is now restricted in food applications. The information on lead migration into foods is limited. The only information available is that lead resists attack by many acids including sulphuric acid.

Safety aspects:

- JECFA (1993): has assigned PTWI of 0.025 mg/kg.b.wt.
- Daily dietary intake of 0.015-0.1 mg (Codex, 1995).

- Lead is mainly absorbed from g-i tract. Lead in blood has half-life of one month and some bones as high as 27 years (Beliles,1994).The toxicity of lead is based on its ability to bind biologically important molecules and then interfere with their function(CE, 1994).

- Due to low safety factor, all use of lead including solders in food contact materials shall be avoided fully.

- Chronic intoxications can arise through the regular consumption of foodstuffs even slightly contaminated with lead. Lead is a typical cumulative poison.

- As a result of high affinity for proteins, lead ions bond with haemoglobin and plasma proteins of blood. This leads to inhibition of synthesis of red blood cells. If the bonding capacity is exceeded, lead passes into bone marrow, lever, and kidneys. Such intoxication leads to encephalopathy in CNS, disturbances in kidney and liver functions leading to necrosis, damage to reproductive organs, anaemia and many metabolic deficiency symptoms.

5.4 Chromium: Chromium is mainly found in trivalent form. Hexavalent chromium is due to anthropogenic sources (Beliles, 1994). Chromium (III) has the ability to form strong, inert complexes with a wide range of naturally occurring organic and inorganic ligands. (Florence and Batley,1980). Chromium is an essential element to man. Chromium is mainly present as Cr (III) in diets. Cereals, pulses, meat, vegetables and unrefined sugar are main sources of chromium.

Metallic food contact materials: Chromium is found in some types of cans and utensils. In cans, it passivates the tinplate surface. Chromium is used in the production of various types of stainless steels and in alloy with nickel, iron, and cobalt. Other food contact materials are pottery, glazes, paper and dyes (Longaard and Norseth, 1986).

Migration to food: chromium (III) migrates to food at pH below 4.5. Stainless steel resists corrosion due to its alloying with chromium. In manufacture of tea by CTC, it is reported that chromium migrates to tea when newly sharpened rollers were used (Manikanandan and Muraleedharan, 2008).The values were 18.2, 18.3, 11.4 mg/kg for first three days respectively when newly sharpened rollers were fixed. The highest rates of chromium and nickel release from saucepans have been from new pans on first use (Flint and Packirisamy, 1997). The chromium and nickel release was tested in rhubarb, apricots, lemon marmalade, tomato chutney and boiled potatoes. The release was about 0.2 mg/kg for apricot and rhubarb after first cooking operation.

Safety aspects:

- JECFA has not evaluated chromium.

- Daily intake: 0.025-0.2 mg. (Codex, 1995)

- Cr (III) is the most stable oxidation state in biological materials and is an essential element for normal glucose metabolism

- Cr (VI) is highly toxic, (Beliles, 1994).

- Chromium is not a safety issue in foods

5.5 Nickel: Nickel is probably an essential element but its deficiency has not been demonstrated. Grains, nuts, cocoa products contain up to 0.8 mg/kg of nickel (NFA of Denmark). In the diet it is found as a complex bound Ni^{++} ions.

87% of nickel is used in alloys and 9% for plating. 3000 types of different alloys are available. Its major use is in the production of high quality, corrosion resistant alloys with iron, copper, aluminium, zinc and molybdenum. Nickel (II) oxide is used in the production of enamel frits and ceramic glazes and in bottles.

Safety aspects:

- JECFA has not evaluated nickel.
- WHO (1997) suggests total daily intake of 0.005 mg/kg b.wt.
- Daily intake from foods is 0.15-0.7 mg (Codex, 1995).
- No adverse effect on health is reported.

5.6 Aluminium: Aluminium is the third most abundant element in the earth's crust. Many of its natural compounds are insoluble in water at neutral pH. Aluminuim occurs in unprocessed foods at 0.1 to 20 mg/kg, 1 mg/kg in eggs, apples, cabbage, corn and 4.5 mg/kg in tea. Higher levels are reported in industrially processed foods where aluminium salts are used as food additives (MAFF, 1993). Aluminium is widely used in food contact materials such as saucepans, aluminium lined cooking utensils, coffee pots and packaging materials such as trays, cans, can seals, and closures (Elinder and Sjogren,1986 and Codex, 1993). Aluminum materials are often coated with resin coatings. Some countries have established requirements for resins and resinous coatings as a measure of safety. Certain aluminium compounds are used in pigments.

Migration to foods: Aluminium and its alloys are resistant to corrosion (Beliles,1994). On exposure to air, the metal develops a thin layer of alumina which is colourless, tough and nonflaky. Therefore, it prevents further oxidation or adverse chemical reaction.

Aluminium reacts with acids below pH of 4.5; it is also attacked by alkalis. Salt content above 3.5% is likely to increase the leaching of aluminium to foods. If molybdenum, is used in the stainless steel, it prevents the action of salts. Use of uncoated saucepans and other aluminium lined utensils will increase the leaching of the metal in foods. In general, cooking in aluminium vessels increases the metal content to less than 1 mg/kg. Acidic foods such as tamarind, tomato, cabbage, rhubarb, and many soft fruits take up more aluminium from the equipment (Hughes, 1992).

Safety aspects:

- JECFA (1989) has assigned the PTWI of 7mg/kg.b.wt.
- Average daily intake is 10mg. (MAFF, 1996).
- Exposure to aluminium is generally considered as not harmful.
- It is excreted by kidneys and only small amount is absorbed.
- Soluble salts are easily absorbed
- WHO (IPCS 1997) has concluded that aluminium is not the origin of Alzheimer's disease.

From the above observations it may be concluded that acidic foods and salty liquid foods are to be stored in unlined aluminium vessels.

5.7 Copper: Earth's crust contains about 70 mg/kg of copper (Beliles, 1994). It exists in two oxidation states, namely cuprous and cupric. It is an essential element to man (Aaseth and Norseth, 1986). Copper is naturally present in most of the foods in the form of copper ions or as copper salts (Codex, 1995). Main sources are meat, fish and milk chocolates in which it is present at 2 mg/kg.

Metallic food contact materials: Copper vessels are traditionally used in many specialized food processing activities, e.g., breweries and distilleries, for cheese making, chocolates, dry vegetables, jams and sweets. In food utensils, copper is generally used unalloyed; however, they are usually lined inside with tin or stainless steel. Copper is attacked by dilute hydrochloric acid or dilute sulphuric acid and is soluble in ammonia (Beliles, 1994). Acidic foods attack copper in utensils.

Safety aspects:

- JECFA (1982) has assigned PTWI of 0.5 mg/kg. b.wt. to copper.
- Daily requirement of 0.05 mg/kg .b. wt. is assigned by JECFA.
- WHO (IPCS, 1998) has established the average daily intake of 0.9 to 2.3 mg
- Acute toxicity is infrequent, rather deficiency is more prevalent.

5.8 Iron: Iron which is present to the extent of 5% is the fourth most abundant element in earth's crust. Iron is the principal element used in steel and other alloys. It is present in ferrous and ferric forms. It is required for the synthesis of blood pigments. Haemoglobin contains about 67% of iron. Iron is present in most foods and beverages. Liver, kidney, beef, ham, egg yolk, and soybeans have iron content in the range of 30 to 150 mg/kg. Iron is chiefly used in most of the utensils, cans and can ends of steel. As cast iron, it is used in pots and pans. Iron is major constituent of steel wherein other metals such as chromium, molybdenum, manganese and nickel are also used to give desired properties to the food processing equipment so the migration of metals into the foods is minimized (Elinder, 1986). In tin plates, iron is used in steel with a tin coating and sometimes with a resin coating for canning of fruits and vegetables. Several iron oxide forms are used as paint pigments (Beliles, 1994).

Food processing equipment, containers and other utensils are the chief source of food contamination by iron. The leaching of iron in cans depends on type of acid medium, pH, temperature of storage.

Safety aspects:

- JECFA (1983) has established a PMTDI at 0.8 mg/kg b.wt.
- Recommended intake is 10 to 28 mg per day set by the regulatory bodies.
- Iron is an essential element. The regulatory bodies view iron not as a toxicological problem but as a deficiency problem. Certain iron salts such as ferrous sulphate and ferrous succinate are used in food fortification.

From the above information it may be concluded that the levels of migration do not constitute a safety problem.

5.9 Manganese: Manganese comprises about 0.1% of earth's crust. About 90% is used in the production of steel as a desulphurising and deoxidizing additive. It exists as Mn (II) and Mn (IV). It is an essential element.

Manganese is reported in most foodstuffs. The chief source is: cereals at 10 to 30 mg/kg, vegetables and fruits at 0.5 to 5 mg/kg.(Beliles, 1994, Codex, 1995).

The main food contact material: manganese is used as an alloying metal in steel and other alloys. It is also used in pigments, glazes and other products which are used in holding food. Migration studies conducted by Lewus et al.1998 suggest that it leaches from stainless steel to simulating liquids at less than 0.002 mg/L. (Saric, 1986).

Safety aspects:

- JECFA has not evaluated manganese.
- WHO (1993) recommends daily intake of 2 to 3 mg.
- SCF (1993) has assigned daily value of 1 to 10 mg as the acceptable range of intake.
- Manganese is an essential trace element and is pre-requisite for bone mineralisation, protein, and energy metabolisation, metabolic regulation, cellular protection from damage caused by free radical species and the formation of glycosaminoglycans (ATSDR, 1997).

Manganese in food contact materials does not give rise to any risk to health.

5.10 Tin: Tin occurs in nature as cassiterite or tinstone, an oxide which is a main source for tin production. As complex bound Sn (II) ions, tin occurs in unprocessed foods at less than 1 mg/kg. In canned foods, tin is likely to be present at higher levels due to dissolution of tin. Codex (1998) suggests a limit of 250 mg/kg for solid canned foods and 200 mg/kg for liquid foods.

The major source of tin in foods is from food contact materials such as from release of tin from cans to acidic foods. Inorganic tin compounds are used as pigments in the ceramic industry (Magos,1986). Organotin compounds stabilize a number of industrial substances that contain chlorine.

Migration of tin to foods: Tin is amphoteric reacting both with acids and bases. Oxygen accelerates reactions in solution (Belile, 1994). The leaching of tin depends on acidity, type of acids, storage period and laquering of the tin cans. The sacrificial anode effect, which results into tin dissolution, protects the can from possible perforation, and protects the products from further degradation.

Safety aspects:

- JECFA (1989) has established a PTWI at 14 mg/kg b.wt.
- Normal diet without canned foods, contains about 0.2 mg tin per day (Codex, 1995).
- Limits of 50 to 250 mg/kg have been laid by different countries.
- No indication of human toxicity due to tin (Codex, 1995). Inorganic tin is poorly absorbed from gastro-intestinal tract. Tin appears to interfere with iron absorption and haemoglobin formation.
- Tin has inhibitory effect on copper, zinc, and calcium absorption (Codex, 1998). Growth depression and alteration in immune function may result from chronic exposure to tin, possibly due to interactions between tin and zinc or selenium. (Codex, 1998).
- Tin was prioritized by Codex for evaluation by JECFA in 2000 on acute toxicity. However JECFA is seeking more information on toxicological studies.

5.11 Zinc: Zinc is an essential element. It appears in the form of zinc ions or zinc salts. Zinc used in the galvanizing of iron and steel prevents the rusting. It occurs in most foods and beverages; main sources are meats, organ meats, whole grain cereals and milk products including cheese (Codex, 1995). Oysters and peanuts may contain up to 100 mg/kg and 30 mg/kg respectively.

Major food contact materials are non-corrosive zinc alloys, brass and galvanised steel and iron products (Elinder, 1986).Coating of iron or other metals with zinc will inhibit rusting or corrosion and offer protection to foods. Zinc contains small amounts of toxic metals as impurities and therefore, a source for such heavy metals in food contamination. Zinc sulphide and zinc oxide are used in paints and ceramics.

Migration information: zinc has a strong tendency to react with inorganic compounds especially their oxides. Zinc galvanized utensils may release zinc and cadmium to foods.

Safety aspects:

- JECFA (1982) has established a PMTDI of 1 mg/kg. body wt.
- The required daily intake is 15 mg (JECFA, 1982)
- The average daily intake is 15 to 20 mg. (WHO, 1993).
- Zinc is one of most ubiquitous of the essential trace metals with absorption varying between 10 to 90%. Zinc is an essential element necessary for the function of a large number of metalloenzymes(ASTDR, 1992).
- Zinc should not be used in contact with wet or humid acidic foods; zinc galvanized utensils must not contain cadmium or release cadmium.

5.12 Cobalt: Cobalt a rare element usually occurs in the ores of nickel, silver, lead, and iron. It is also a constituent of vitamin cobalamin.

Cobalt is reported in green leafy vegetables. Plants like lettuce, beets, cabbage, spinach and sweet potato contain about 0.1 to 0.7 mg/kg (Beliles, 1984).

In food processing equipment cobalt is used in the production of high strength alloys (Elinder and Friberg, 1983).Other food contact materials are glass and ceramics in which cobalt oxide is used to neutralize the yellow tint. Larger amounts of oxide impart blue colour. Oxide is also used in enamel coatings on steel to improve the adherence of the enamel to the metal.

Migration: cobalt is relatively unreactive metal and does not oxidize in dry or moist air at ordinary temperature. It reacts with most acids but becomes passive in concentrated nitric acid. It is not attacked by alkalis.

Safety aspects:

- JECFA has not evaluated the toxicity of cobalt.
- Essential daily intake is 0.2 to 1.8 mg (Codex, 1995).
- Cobalt is an essential element. 5 mg in body is required for cobalamin to prevent pernicious anaemia a fatal illness. Generally, it has low toxicity. Effect on heart, blood pressure, abdominal pain, breathing difficulties, have been reported due to ingestion of large amounts of contaminated

beer. In beer, cobalt is used to inhibit the fermentation.

No specific guidelines for migration for cobalt into foods are suggested by any regulatory bodies as cobalt does not pose any risk to health as the alloys are found only in glass and glazed pottery.

5.12 Arsenic: The sources for arsenic are burning of coal for power generation, smelting of ores, gold and base metal processing, metallurgical applications integrated electronic circuit, arsenical pesticides, fungicides and weedicides, war gases and inorganic compounds. Arsenic is also reported in ground water in certain regions.

Safety aspects:

JECFA has assigned PTWI of 15 microgram/kg bw.

As (V) present in foods has relatively low toxicity

As (III) present in natural waters through dissolution of minerals and ores

Guideline value for drinking water; 0.01 mg./L

6.0 Conclusion:

Stainless steel alloys especially food grade no. 304 and 316 are being extensively used in food processing, storage and transport while for packaging aluminium foils are used. Other alloys such as bronze, brass, german silver and nickel-titanium are also used in some applications. Generally, stainless steel and aluminium alloys are the primary materials used in food processing. Plastics and other metals may also be used but not lead and cadmium plated materials. Food contact surfaces must be smooth, non-adsorbant, non-leaching, and insoluble in the food. Some good practices to be followed to prevent premature wear and tear and to prolong the life of food processing equipment have been discussed by Mizier, M. O.(1994). Aluminium alloys are not as strong or durable as stainless steel alloys; they find application in processing, handling, and packaging of foods and beverages. In addition to resistance to corrosion, many of these applications depend on the non-toxic nature of aluminium and its salts, as well as freedom from catalytic effects that cause product discolouration.

The constituent elements of an alloy migrate from the alloys to food; the migration of alloying element is in general lower compared to migration from non-alloyed metals due to micro structural binding of the element in the alloys. Migration is controlled by the atomic binding forces. This chemical binding anchors the alloying elements in place throughout the alloy and are not free to migrate independently to the surface.

Considering the availability of specialized stainless steel alloys such as martenistic, ferrite, austenitic and super austenitic alloyed in different proportions of iron with carbon, chromium, molybdenum, copper and vanadium followed by pickling and passivation which offer resistance to corrosion, different types of foods such as acidic foods, alcoholic beverages, milk and milk products, oils and fats and products with increased salt content may be processed with minimum of migration of constituent metals from the processing equipment. Although stainless steel is generally resistant to corrosion, it is not immune in a chloride containing environment. Hydrochloric acid is used in some cleaning and processing liquids. Corrosion products should be removed immediately as they impede proper cleaning of surfaces. In fact, strategic maintenance programmes should be part of the plant's overall vision of the future, which aims at boosting production efficiency and also safety of the products.

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SAFETY AND REGULATORY ASPECTS OF FOOD ADDITIVES

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Processed foods have become a way of life in the modern world. Manipulation of chemical and physical properties, facilitated greatly by modern food technology and addition of food additives has created a plethora of innovative food products that offer consumer greater convenience, variety, safety, nutrition and quality.

Food additives despite their modern-day associations, have been used for centuries for preservation, for providing improved appearance or desired texture and flavour. Food additives play an important role in today's complex food supply. Never before has the range and choice of foods been so wide, in terms of availability. Food additives help in meeting consumers' demand for variety and choice, greater ease and convenience and higher standards of safety and wholesomeness, at affordable prices.

Food Additives:

1. Definition: A food additive is defined as "any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food whether or not it has nutritive value, the intentional addition of which to food for a technological purpose in the manufacture, processing preparation, treatment, packaging, transport or storage of such food results, or may be reasonably expected to result, in it or its by-products becoming directly or indirectly a component of such foods". (Council Directive 89/107/EEC)

Functions:

Additives perform a variety of useful functions in foods. Foods are subjected to many environmental conditions, such as temperature changes, oxidation and exposure to microbes which can change their original composition. Food additives play a key role in maintaining the food qualities and characteristics the consumers demand, keeping food safe, wholesomeness and appealing from farm to fork.

Based on their function, Codex Alimentarius Commission classifies food additives as under:

Functional classes (for Labelling purposes)	**Function**	**Example**
1. Acid	Increases the acidity and/or imparts a sour taste to a food acidifier	Phosphoric acid, citric acid
2. Acidity Regulator	Alters or controls the acidity or alkalinity of a food	Calcium oxide, Calcium carbonate
3. Adjuvants	Density adjustment agent for fats, oils in beverages, encapsulating agents for flavour	α, β, γ – cyclodextrins, polyethyleneglycol
4. Absorbent	To remove undesired pigments	Activated carbon
5. Anti caking agent	Reduces the tendency of particles of food to adhere to one another	Carbonates, silicates and phosphates of Calcium and Magnesium
6. Antifoaming agent	Prevents or reduces foaming	Micro crystalline wax, oxystearin, petroleum jelly, poly dimethyl siloxane

Functional classes (for Labelling purposes)	Function	Example
5. Antioxidant	Prolongs the shelf-life of foods by protecting against deterioration caused by oxidation, such as fat rancidity and colour changes	BHA, TBHQ, citric acid
7. Bulking agent	A substance, other than air or water, which contributes to the bulk of a food without contributing significantly to its available energy value	Sorbitol, mannitol, isomalt, bee's wax, ethyl cellulose
8. Carrier	For carrying the desired component	Bee's wax, benzoyl alcohol, glycerol
9. Clouding agent	To keep cloudiness	Gum, sucrose-acetate.
10. Colour	Adds or restores colour in a food	Chlorophyll carotenes, synthetic colours-tartrazine
11. Colour retention agent	Stabilizes, retains or intensifies the colour of a food	Ferrous lactate, copper sulfate, magnesium chloride
12. Emulsifier	Forms or maintains a uniform mixture of two or more immiscible phases such surface as oil and water in a food	Alginates, gums
13. Extraction solvent	For extraction of the component	Acetone, butanol
14. Filtering aid	For filtration	Diatomaceous earth

Functional classes (for Labelling purposes)	Function	Example
15. Firming agent	Makes or keeps tissues of fruit or vegetables firm and crisp, or interacts with gelling agents to produce or strengthen a gel	Calcium chloride, magnesium chloride
16. Flavour enhancer	Enhances the existing taste and/or odour of a food	Calcium-5'-guanylate calcium-5'-inosinate
17. Flour treatment agent	A substance added to flour to improve its baking quality or colour	Benzoyl peroxide, calcium peroxide, calcium oxide, chlorine
18. Foaming agent	Makes it possible to form or maintain a uniform dispersion of a gaseous phase in a liquid or solid food	Carbon dioxide, nitrogen, dichlorofluro methane
19. Gelling agent	Gives a food texture through formation of a gel	Alginic acid
20. Glazing agent	A substance which, when applied to the external surface of a food, imparts a shiny appearance or provides a protective coating	Carnuaba wax
21. Humectant	Prevents food from drying out by counteracting the effect of an wetting agent atmosphere having a low degree of humidity	Glycerol, mannitol polydextrose

Functional classes (for Labelling purposes)	Function	Example
22. Preservative	Prolongs the shelf-life of a food by protecting against deterioration caused by agent, bacteriophage control agent, microorganisms	Benzoate KMS
23. Propellant	A gas, other than air, which expels a food from a container	Argon, butane, carbon dioxide
24. Raising agent	A substance or combination of substances which liberate gas and thereby increase the volume of a dough	Ammonium carbonate
25. Stabilizer	Makes it possible to maintain a uniform dispersion of two or more immiscible retention agent, foam stabilizer substances in a food	Gum, fatty acid esters
26. Sweetener, synthetic	A non-sugar substance which imparts a sweet taste to a food	Aspartame
27. Sequesterants	For removing metals	EDTA salts

Safety issues:

Food additives are very carefully regulated and the general criteria for their use is that they perform a useful purpose, are safe and do not mislead the consumer.

Excessive levels of an additive on inclusion of an undeclared additive may be directly dangerous in some instances, but food additives themselves, when

used properly, pose little health risk given current scientific evidence. However, this does not negate their possibility of inducing disease from years of ingestion at low levels.

For the health-conscious consumer, a good rule of thumb to follow is to avoid the foods that contain the questionable additives. Consumer and scientific interest, government supervision, and industry compliance are keys to the safe use of food additives. Some concerns about food additives:

- The ubiquitous additives, sugar and salt are well documented for their disease potential.
- Vinyl chloride monomer – implicated in brain, lung and lymphatic tumor development liver cancer.
- Styrene – potent mutagen
- Nitrates and nitrites – form carcinogenies N-nitroso compounds may oxidize blood oxyglobin to methemo globin – oxygen cannot bind this – may lead to cyanosis and suffocation.
- Sulphites – sensitive individuals, especially those with asthama, can react to sulfite with unpredictable and even life-threatening severity.

Non-nutritive sweeteners:

- Saccharin – anticipated to be a carcinogen, delisted in Canada.
- Aspartame – a dipeptide of L-asparlic acid and methyl ester of L-phenyl alanine; during digestion-hydrolysed into aspartic acid, phenyl alanine and methanol. Chronic methanol content can cause visual impairment.

What is Safe Food:

Regulatory authorities that oversee food production are aware of the impact of contamination and additives. Regulatory authorities now prefer to use quantitative risk assessment to help define food safety as well as to determine

optional intervention strategies, **scientific risk assessments** have reportedly became the foundation for food safety worldwide with the issuance of SPS agreement by WTO.

American Academy of Colloquim on Food Safety (1998) describes safe food as follows: Safe food if properly handled at all steps of production through consumption is reliably unlikely (i.e., the probability is low and the variability is small) to cause illness or injury.

Characterization of Food Hazards:

Hazard is a "biological, chemical, or physical agent that is reasonably likely to cause illness or injury in the absence of its control".

- Biological hazards: Microbial pathogens
- Chemical hazards: Contaminants and additives.
- Physical hazards: Glass, wood, plastic, stones, metal and bones.

Hazard characterization is the qualitative and quantitative evaluation of the nature of the adverse effects associated with biological, chemical and physical agents that may be present in foods.

Risk analysis frame works for chemical hazards

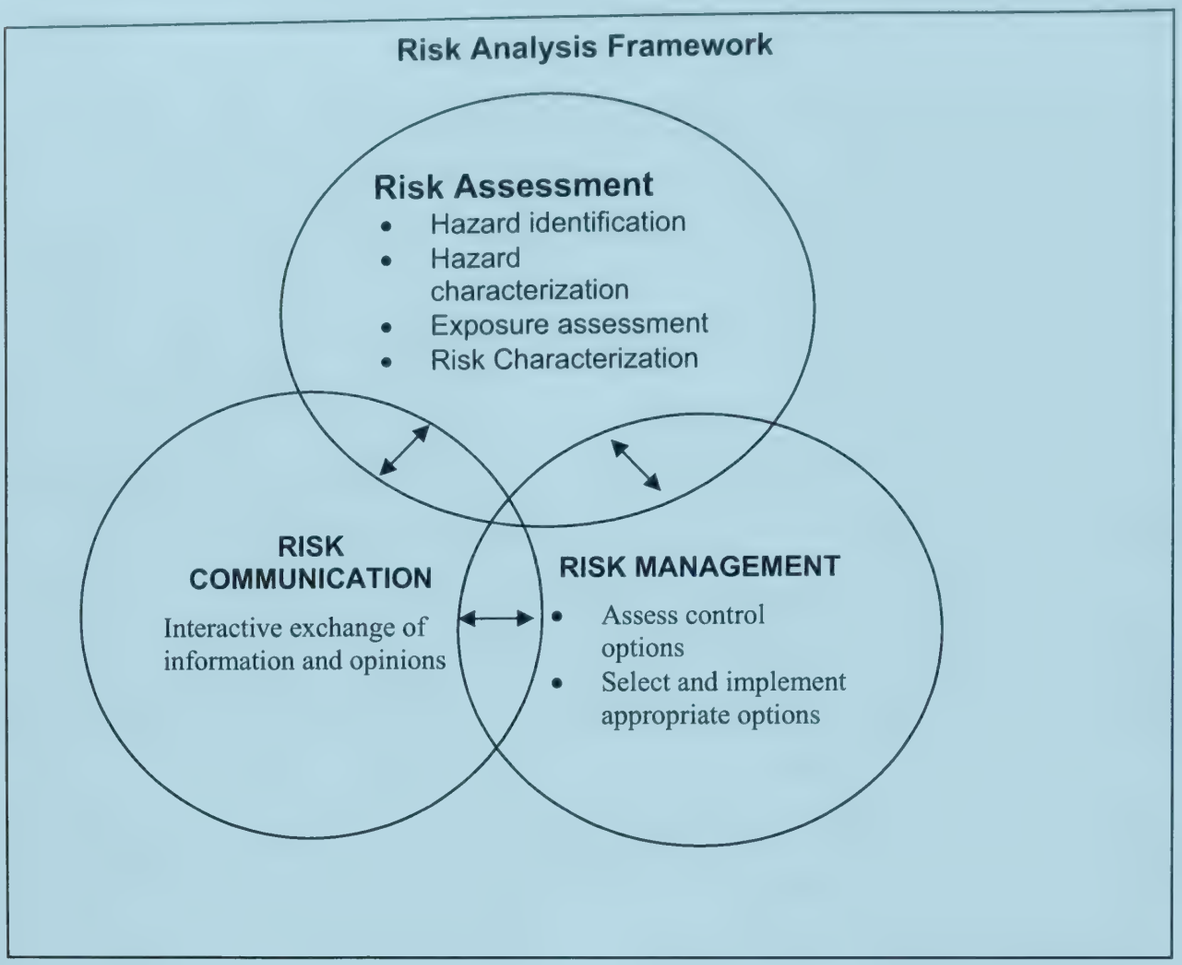
Human individuals and societies have been identifying risks and managing them since ancient times by various procedures, including establishing codes of practice and formal laws.

Risk is defined with responses to three basis questions:

1) What can happen (scenario)
2) How likely it is (likelihood)
3) What are the consequences (consequence)

Risk analysis is the field that provides the public with the information needed to make informed decisions about risks and how to manage them.

A common risk analysis framework encompasses three components (I) Risk Assessment (II) Risk Management and (III) Risk Communication.



I. Risk assessment: defined as "identification and quantification of the risk resulting from a specific use or occurrence of a chemical, physical or microbiological agent, taking into account possible harmful effects on individual people or society of using the agent in the amount and manner proposed and all the possible routes of exposure.

Risk: chance or probability of an adverse health effect occurring and the severity of that effect.

Risk assessment is a scientific process, conducted by scientific experts, which may begin with a statement of purpose intended to define the reasons that

the risk assessment is required and support the aims of the subsequent stages of risk management.

Risk assessment involves:

Ia. Hazard identification

Ib. Hazard characterization

Ic. Exposure assessment

Id. Risk characterization

Ia. Hazard Identification:

It is defined as "determination of substances of concern, their adverse effects, target population and conditions of exposure, taking into account toxicity data and knowledge of effects on human health, other organisms and their environment (IUPAC). The data used in hazard identification may include results from many different types of study, including:

- Human studies – epidemiology, case reports, or volunteer studies
- Toxicity studies conducted in laboratory animals
- Alternative approaches, including use of in vitro models such as cell cultures or tissue slices, and comparisons with structurally related chemical substances.

Hazard identification – the food additives

Key observations:

- Toxicity studies in experimental animals and models, including short-term studies in rodent and non-rodent over a period of upto 10% of the expected life scan (i.e. 90 days in rat, 1 year in dog).
- Maximum dose limit of 5 g test material per kg of body wt.
- Additional studies may be required to investigate neurotixicity.
- Consider whether a threshold mechanism can be assumed
- Identify the effect seen at the lowest dose levels (the critical effect).
- Consider the relevance to humans.

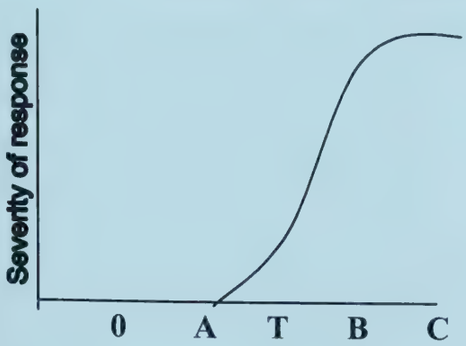
Examples of types of adverse effect caused by additives:

Functional changes (Other changes)	• Reduced weight gain • Organ enlargement
Morphological changes	• Histopathological lesions
Mutagenicity	• Heritable changes to DNA, genes and chromosomes, with the potential to cause cancer or fetal abnormalities
Carcinogenicity	• Cancer
Immunotoxicy	• Sensitisation (leading to hypersensitivity or allergy) • Depression of the immune system (leading to increased susceptibility to infection)
Neurotoxicity	• Behavioural changes, deafness, tinnitis, etc.
Reproductive effects	• Impaired fertility • Embryotoxicity • Teratogenicity • Other developmental effects

IB. Hazard Characterisation

Closely linked to hazard identification. It often is based on evaluation of the same animal toxicity studies. The focus here is on the relationship between dose and response i.e., quantitative species extrapolation.

Typical dose – response relationship



Dose in mg / kg of body wt
(log scale)

Points A, B, and C dose levels used in the toxicity.
Point T: Theoritical threshold level.

Hazard Characterisation:

Toxicity studies in experimental animals.

- Establish highest dose level without effect (NOAEL) in the study that identifies the critical effect (as in __) or model the dose response relationship to identify a benchmark dose.
- Toxicokinetic studies
  - Data on absorption, distribution and excretion and identification of major metabolites.
  - Investigation of the effects on dose level and duration on the metabolism of the test material.
  - Comparative studies in human volunteers.
- Establish Acceptable Daily Intake (ADI)

$$ADI = \frac{NOAEL}{\text{Safety factor (100)}}$$

Ic. Exposure Assessment:

Exposure assessment is the qualitative and / or quantitative calculation of the likely intake of biological, chemical or physical agent via all relevant sources. Here, for food additive intake, an understanding of amount of food additive present and amount of food consumed is required.

Exposure = Food consumption x food additive level

When the particular food additive is present in more than one food commodity, the estimated exposure would represent the summation of all the individual commodity exposures.

Information on pattern of food consumption is obtained from survey on the type and quantities of food consumed by individual over specific periods.

Exposure Assessment – Food Additive

Estimation of maximum daily intake from foods

- Content in foods determined by analysis
- Consumption of food additive from all food commodities estimated from survey data
- Calculation of maximum daily intake from foods

Intake of a chemical is normally expressed as the amount ingested per unit time (e.g. mg / day) and related to the body weight of an average individual (i.e., mg / kg body weight / day). This allows ready comparison of intakes in human populations with the doses used in animal toxicity studies.

Id. Risk Characterisation:

Risk characterization is "the qualitative or quantitative estimation, including attendant uncertainties, of the probability of exposure and severity of known or potential adverse health effects in a given population based on hazard identification, hazard characterization and exposure assessment.

It means, estimating how likely it is that harm will be done and how severe the effects will be. The outcome may be referred to as risk estimate, or the probability of harm at given or exposure levels.

For food additives, the results of risk characterization may be comparison of estimated intake or exposure with acceptable or tolerable level of intake which is considered not likely to cause harm if repeated daily over an entire lifetime.

Risk characterization – the food additive

- Compare the total maximum daily intake with ADI.
- Intake lower than ADI – proposed additive use acceptable.
- Intakes potentially higher than the ADI – consider risk management options.

Risk assessment provides the basic information upon which risk management decisions are made, and the principles of risk assessment are generally defined by government departments. The risk assessment is usually conducted by expert committees, on behalf of the government departments, particularly with respect to defining acceptable levels of chemicals in food.

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II. Risk Management:

In managing risk, the Risk Manger considers the results of Risk Assessment and other factors, including economic, political, social, and technological inputs or limitation, to develop policies to manage the risk. It also needs to take into account the public's perception of risk. Risk management strategies may be regulatory, advisory or technological and take into account factors such as the size of the exposed population, resources required and available, costs of implementation and the scientific quality and certainty of the risk assessment.

General Principles of Food Safety, Risk Management FAO/WHO Expert Committee on the Applications of Risk Management to Food Safety

1. Risk management should follow a structured approach.
2. Protection of human health should be the primary consideration in risk management decisions.
3. Risk management decisions and practices should be transparent.
4. Determination of risk assessment policy should be included as a specific component of risk management.
5. Risk management should ensure the scientific integrity of the risk assessment process by maintaining the functional separation of risk management and risk assessment.
6. Risk management decisions should take into account the uncertainty in the output of the risk assessment.
7. Risk management should include clear, interactive communication with consumers and other interested parties in all aspects of the process.
8. Risk management should be a continuing process that takes into account all newly generated data in evaluation and review of risk management decisions.

- To recommend specifications of identity and purity of food additives for adoption by the commission;
- To consider methods of analysis for their determination in foods; and
- Consider and elaborate standards or codes for related subjects such as the labelling of food additives when sold as such, and food irradiation.

Standards for Food Additives and their level in foods developed through the work of CCFAC and JECFA by an-eight step process

1. Commission decides to elaborate a standard and assign the work to the committee (CCFAC).
2. Codex secretariat – prepares the proposed Draft Standard.
3. Draft sent to Governments and International Organizations for comments.
4. Secretariat forwards comments to the committee.
5. Committee reviews the comments and sends proposed Draft Standard to the commission for adoption as a Draft Standard.
6. The commission sends Draft to Government and International Organizations for comments.
7. Comments forwarded by secretariat to the committee.
8. After considering the comments, the Draft Standard is returned to the commission for adoption on a Codex Standard.

Joint FAO/WHO Expert Committee on Food Additives (JECFA)

Functions:

- Reviewing latest knowledge and expert information and making it available to the two organizations, FAO and WHO.
- Formulating technical recommendations; and
- Making recommendations designed to initiate, stimulate, and co-ordinate the research necessary to fulfill their terms of reference.

JECFA specifications are minimum requirements for the composition and quality of food-grade additives. These specifications are meant to be used internationally. JECFA specifications in their entirety describe substances of food-grade quality, and as such, they are directly related to toxicological evaluations and to good manufacturing processes. JECFA periodically reviews specifications test methods to update the analytical methodology of specifications.

JECFA specifications for food additives are published by FAO. In 1992, all specifications from 1st to 37th JECFA meetings were published in a consolidated document – compendium on Food Additive specification, FAO Food and Nutrition papers 52, two volumes.

The on-line edition of the compendium of Food Additive specifications and guide to specifications (FNP 5 rev. 2) contains a consolidated and updated editions of all documents related to specification of food additives from 1st to 57th JECFA meeting. The databases are fully searchable.

Two separate databases can be accessed by Internet –

1. Specifications for food additives
2. Specifications for flavouring agents

Also, Part I of the database are listed by functional class with flavouring agents listed separately both alphabetically and by "JECFA number'"

Part II, provides more detailed information on food additives.

Indo-US Bilateral Workshop-cum-Training Programme on POST HARVEST TECHNOLOGY, COLD CHAIN MANAGEMENT & FOOD SAFETY ISSUES

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